THE ESTABLISHMENT AND EARLY MANAGEMENT OF SOWN PASTURES

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Britain is a country of grasslands, and over its greater part grassland is likely, by mere virtue of an equable climate, always to be the predominant feature of the agricultural landscape. The natural "climax" vegetation over the vast proportion of Britain, however, is forest. There is substantial evidence to show that most of the lowlands in prehistoric time were covered by more or less dense forest. On the richer soils oak forest predominated; on many soils of lower inherent fertility and in less favoured situations, birch replaced oak. Under other conditions beech, ash, Scots pine and others were the important trees of the primary forest. The shrubby undergrowth would consist variously, in conformity with the soil and climate, of the following: hazel (on good land), hawthorn, blackthorn, holly, yew and juniper, among others. The floor of the virgin forest is likely to have carried various ferns, including bracken in the less densely shaded parts, as well as a proportion of native grasses, especially where the tree growth allowed sufficient light to enter to the forest floor. One may picture the primeval forest floor with perhaps a sparse development of such grasses as cocksfoot, fog, tussock, the poas and others. Ryegrass, fescue, clover, various herbs and other light-demanding plants would occupy the forest clearings.

Some such picture as this of primeval England is fairly generally accepted, but what is not so well recognized is the fact that remnants of these various phases of primitive forest are still to be found, though hardly in their pristine glory. The fundamental point to be stressed is that the grasslands (as well as the arable land) of England are in their present form *man-made*, and their maintenance as grasslands is due almost entirely to the influence of man and his domestic animals. British grasslands are, therefore, artificially induced, just as are the grasslands of the high-rainfall belts of Australia and New Zealand. In fact, the only fundamental difference between the so-called permanent pastures of England and those of the North Island of New Zealand is that the latter are but a hundred years out of forest, whereas many of ours are upwards of a thousand years old. Because of their greater age, they are probably more static as grasslands and will not revert to scrub and low forest with such rapidity as will their New Zealand counterparts. Revert to forest they will, however, just as surely as those of New Zealand, unless man and animal give them constant attention. All this emphasizes the fact that British grasslands are maintained in a relatively stable form purely as a reflex of the stability of management and land utilization. Once the management of the grassland is changed, so will there be a comparable change in the botanical make-up of the pasture. Normally, a system of management which involves heavy stocking and the close defoliation of the herbage induces a pasture complex in which ryegrass and white clover tend to dominate. Thus, on the more fertile lowlands of England, closely grazed and heavily stocked, fields will usually be classed as ryegrass/white clover pastures. On the poorer soils an equally severe system of defoliation of the herbage may induce *Agrostis* with white clover, while on the moorland soils of low inherent fertility, long-continued close-cropping of the herbage will often establish an *Agrostis*/fescue pasture characteristically devoid of legumes. There is, therefore, a relationship

between the natural fertility of the soil complex and pasture type that is induced under any given system of pasture utilization and management.

Within the confines of England and Wales (and the same may be true for Great Britain as a whole) there does not, however, appear to be any direct *climatic* relationship between the various types of grassland. Thus, we may find ryegrass/white clover pastures developed on the lowlands of East Anglia, where the mean annual precipitation is below 25 inches, whereas, on the other hand, we find pockets of a precisely similar pasture type high up on the Welsh hills at elevations above 1000 feet and where the annual rainfall is in excess of 50 inches. It is of course true that the gross output of grass will be greater on the lowlands, and this is particularly reflected in seasonal output. The colder weather of both early spring and late autumn shortens the annual period of active growth under these " natural " conditions. If, however, the appropriate system of grassland farming, coupled with changes in pasture management, were adopted on hill and lowland respectively, the output from both habitats could be increased. The *relative* increase on the hill habitats would, however, be so much greater that the total influence of climate as such would be offset to a considerable degree and the gross output from the two situations by that much brought closer together.

In much the same way as we find ryegrass pastures developed " naturally " in different parts of the country and under contrasting conditions of climate and soil, so also we find other pasture types spread out all over this country. For example, the *Agrostis* pasture type is developed over considerable areas and on widely different geological formations, and at varying altitudes from sea-level to the mountain plateaux at upwards of 1500 feet. Similarly, fescue pastures are not only characteristic of the low-rainfall south-England Downs (calcareous soils derived from the Cretaceous chalks) but cover many thousands of acres of unreclaimed mountain land in England, Wales and Scotland, often on very acid soils and in high rainfall. The established facts and all the experimental evidence at our disposal suggest, therefore, that within the confines of Britain, with its fairly varied climate and very varied soil formations, neither climate nor soil have an overruling influence upon the potential grassland type which can, under human guidance, be developed at any given location in this country. The evidence rather suggests that factors within direct human control play the more important part in determining the character of the grassland. Thus, the combined influences of (*a*) the seeds mixture, (*b*) the management of the established sward, and (*c*) fertilizers applied either through animal excreta or by means of the manure drill, largely determine the botanical make-up of the grassland and will also have an important bearing upon the productivity, stability and persistence of the pasture as such.

Having regard to the foregoing, we cannot in this country speak of " natural " as opposed to " artificially-induced " grasslands, for the vast bulk —if not the whole—of our grasslands, including the moorland grazings, are, in fact, " artificially induced " in the sense that they are the products of centuries of biotic influence largely expressed in terms of the influence of man and his farm animals. It is more appropriate, therefore, for us in Britain to deal with our grasslands under the two classes : (1) *uncultivated*—which will include the greater part of our rough and hill grazings, and (2) *cultivated*—

Fig. 1.—The Gloucestershire Cotswolds. Elevation 500-1000 feet. Annual rainfall 27-30 inches, with long periods of dry weather in spring and summer. Tor grass (*Brachypodium pinnatum*), characteristic of the permanent pastures. High-class long-duration (3-6 year) leys can be maintained without difficulty.

including the whole of the permanent pastures and meadows of our farmlands as well as the considerable acreage of short- and long-term leys. It is to be emphasized, however, that such is the influence of pasture management exercised over a prolonged period that there is no precise line of demarcation between these several groups. Thus, one group will tend to merge gradually into another group. There is, for example, no sharp line of distinction between the ley and the permanent pasture. The transition from the " ley phase " to permanent grass is usually a gradual process. Normally, the longer a ley remains in grass, the more closely does it resemble permanent grass, and its function as a ley may be said to have finished when the species originally used in the seeds mixture have gone and are replaced by unsown grasses, clovers and herbs.

Before the outbreak of the present war, the approximate acreages of arable and grassland in England and Wales were :—

	Thousand acres	*Percentage*
Tillage crops	6,855	22·7
Temporary leys	2,071	6·8
Permanent grass	15,702	52·0
Rough grazings	5,601	18·5
	30,229	100·0

During the war years the acreage in permanent grass (= cultivated grassland) will have been reduced by about 6 million acres, and the tillage land increased proportionately. There is an aggregate increase of about 45 per cent. in the acreage of leys since the war began. The total area of rough and hill grazing is not likely to have been materially affected. Neither will the war period have greatly changed the hill pastures themselves, for, to all intents and practical purposes, the Nation has done nothing to its hill lands. The hills represent a very valuable agricultural asset which could be greatly developed for the common good, both as stock-rearing units and as summer pleasure grounds for our large urban populations.

The Ley

The modern concept of the ley is as a *farm crop* and as an integral part of the cropping rotation. Such is the emphasis, that the ley is coming more and more to be regarded as the pivotal crop in any rotation. The function of the ley is twofold : first, to build up soil fertility, including crumb structure and soil condition generally ; and, secondly, to provide a heavy crop of nutritious grass for as long a season as possible and for as many years as the ley is required. A well-conceived and properly-balanced grass-legume ley will fulfil these conditions better than permanent grassland. It is usually said that permanent pasture *builds* up fertility—the evidence rather more correctly suggests that the old swards may be said to *lock* up fertility, especially in terms of the organic residues. The wartime cropping programme in England has taught us by experience that the majority of our old grasslands did not provide the immediate fertility necessary to grow full arable crops. Taken

generally, the old pastures were strikingly short of phosphates and of lime: both these plant foods had to be applied through the manure drill before the newly-cultivated lands would bear a full crop. Where a derelict condition had developed—and, indeed, in the generality of cases—the old pastures did not yield their fertility unless special precautions were taken to ensure that, by timely ploughing and other cultivations, sufficient rotting of the old turf took place. This often meant that the farmer had to apply soluble nitrogenous fertilizers in order to quicken the rate of initial decomposition.

Given good and timely cultivations, together with the necessary applications of lime and artificials, events have shown that our old pasture fields, however derelict and unproductive they may have seemed in pre-war days, can produce heavy arable crops. Indeed, given these essentials, the grass fields of pre-war days have produced heavier wartime crops than has the pre-war arable land. After ploughing-up, well-balanced leys are, however, producing still heavier arable crops, and that without excessive cultivations and with the minimum of added artificial fertilizers.

The new-found conception of the ley denotes a fundamental change in approach to the whole farming problem in relation not only to rotations, but to the various facets of the soil fertility problem. English medieval agriculture was based on the manorial and open-field systems. This involved intensive cropping on the village fields, which, in any case, seldom accounted for a large proportion of the land surface as a whole. Then followed the Enclosure Acts of the eighteenth century. By the close of that century the greater part of the lowlands had been fenced and made into farms resembling those of the present day. During the first part of the nineteenth century there was a considerable extension of the acreage under tillage crops, which reached a peak in the 1870-1874 period. This intensive tillage, however, did not directly involve all the land on the farm. Various cropping rotations were built up, these largely having as their bases the foundation laid by the Norfolk four-course rotation, namely: corn, roots, corn, one-year ley. In some districts (as on the heavy clays) this four-course rotation was extended to a six-course, so as to read—corn, beans, corn, roots, corn, one-year ley. In Wales and certain other districts of the west and north of Britain, the extended rotation might read—corn, corn, roots, corn, five to seven-year seeds ley and back to corn again—a nine to eleven-year rotation. In parts of Scotland, notably Aberdeenshire, the rotation often became—corn, roots, corn, three-year ley—a rotation which has acquired a wide reputation throughout Scotland and elsewhere. Similarly conceived rotations have long been employed on Tweedside on the Scottish-English border, in the Eden Valley in Cumberland, and in a few other districts. It has to be clearly understood that these far-flung districts of pre-war ley farming, including Aberdeen, Ayrshire and other parts of Scotland; small parts of the counties of Cumberland, Northumberland, Hereford, Somerset, Devon and Cornwall in England; parts of Pembroke, Cardigan, Anglesey and others in Wales, did not in the aggregate represent more than a very small portion of our total agricultural acreage. By far the greater part of our tillage land was in intensively-cultivated blocks (as in East Anglia and other arable districts) or in similarly intensively-cultivated *fields* on farms throughout the whole country. The typical Midlands dairy farm of pre-war days consisted

of a block of fields under intensive arable cropping (based on the one-year ley), whereas the remainder of the farm, and usually the greater proportion, was in permanent grass. The latter had either never been under the plough or had not been cultivated since the 1870 period. Many districts had gone wholly to permanent grass and the art of ploughing and cultivation had been lost altogether for more than a generation.

It was evident in pre-war days that the ley-farming districts of Britain were producing at a higher general level than the permanent grass districts. On the basis of experiments conducted at Aberystwyth and elsewhere it was reasonable to suppose that this higher level of production was directly attributable to the ley *per se*. None of these ley-farming districts, however, had fully exploited the possibilities of the ley as a grass-producing unit. In the main, they had followed traditional rotations built around local experience. They were rotations that " worked " in practice, and not only did they serve to maintain the standard of soil fertility, but the fertility was enhanced as the years went on. This was particularly true where leys of three years or longer were used, and where the rotation did not include more than two or three corn crops. The ley added to fertility and so also did the root crop (to which dung was applied), especially where the roots were fed *in situ* and the residues returned direct to the soil. The ley and root crop together provided, therefore, a credit side to soil fertility which was greater than the debit consequent upon the removal of two or three corn crops. A rotation (such as the Aberdeenshire) which included four years of ley *cum* roots and only two corn crops was likely, therefore, to be a soil fertility-building rotation. The well-acknowledged success of the Aberdeenshire rotation is, to an appreciable extent, founded on this important feature.

The Problems of Establishment of the Ley

In districts of high rainfall * throughout Britain, initial establishment of sown seeds presents little or no difficulty, so long as the normal tenets of good husbandry are followed. There must be a reasonable tilth, appropriate plant foods must be available, a sensibly-balanced seeds mixture should be used and efficient standards of grazing management need to be applied. Granting that these fairly simple rules are followed, success is usually assured. The establishment of the ley in the belts of lower rainfall of the east and south of England presents, however, greater difficulties, but these are now being solved. Recent research has shown that, given certain additions to the rules as formulated for the high rainfall condition, the take of seeds can equally be assured under conditions in the " below 30 inches " rainfall belts. The chief factors concerned will be dealt with in detail in the subsequent parts of this paper.

Pre-cultivations

The object of the whole series of operations involved in land cultivation for the ley must be to produce a good surface tilth with the ground fully

* For this purpose the districts of high rainfall may be defined as those receiving an average annual rainfall of 30 inches or more. Low rainfall belts are those receiving less than 30 inches per annum. Broadly speaking, the latter belt in England lies to the east of a sinuous line stretching from Bournemouth, through Worcester, to Derby and York.

consolidated to plough depth. To ensure this, the land should be ploughed some months prior to sowing. Thus, if sowings are made in the early spring, the ploughing should be done in late summer and autumn. This not only allows the frosts and rains of winter to ameliorate and weather the topsoil, but also gives time for the whole soil to ploughing depth to settle and become consolidated naturally. These timely cultivations make the spring work less arduous on the majority of our soils. On certain of the heavy clays, successful establishment of the ley is a hazardous business unless the ploughing has been done in the autumn and the land fallowed over the winter. When starting with derelict turf which is to be reseeded direct to a ley without the intervention of an arable rotation, it is doubly important to plough early, so as to effect not only the necessary amount of consolidation and weathering of the soil, but also in order to rot the old turf. In these cases, breaking the turf before ploughing is an advantage. This has been done by the use of heavy disc harrows (weighing up to 25 cwt.) drawn behind crawler-tractors. It has also been done in other ways, such as by the use of heavy cultivators, heavy drag harrows and by the pitchpole harrow. The aim is to break up the turf before ploughing, so that air and water can enter freely. This starts up the processes of decomposition, which go on at an accelerated rate after the land is ploughed up. Pre-discing and other pre-ploughing surface cultivations have been particularly successful on the difficult clays of the Midlands and in other areas where derelict turf was being reclaimed and brought into arable cultivation during the war years.

Spring cultivations immediately prior to sowing the seeds mixture consist of rolling and harrowing to provide a fine seed-bed for the seeds. The land is brought to as fine a tilth as possible, before the seed is planted, and the surface is left in a firm condition after planting by the further use of harrows and heavy rollers. The evidence shows that the firmer the seed-bed, the more assured is successful establishment, other things being equal.

Further cultivations after sowing and during the period of initial growth

Various methods are employed to cover the seeds. Traditionally, the light harrows have been used and followed by the roller. This method has been fairly uniformly successful in the high rainfall belts, but recent research has shown that in the drier districts the seeds require to be planted deeper. This may be done by covering with heavy tined harrows or even by running the disc harrow over the land more than once if necessary. Modern seed drills will plant the seeds at any required depth. These points will be discussed more fully below in the section dealing with depth and method of planting.

In a number of cases the frequent use of the heavy smooth roller during the first few weeks after sowing the seeds has proved beneficial. This is particularly true on light and peaty soils that tend to puff-up unduly. It has been generally true, too, in cases of direct reseeding after old turf and especially during long spells of dry weather following sowing. None of the heavy rollers nor any other of our ordinary farm implements, however, have proved in practice to be as beneficial as the advent of the grazing animal on to the new and establishing ley. This matter is also dealt with later.

Method and depth of sowing

The method of sowing (largely in terms of drilling *versus* broadcasting) the seeds has for long been a highly controversial topic among farmers and technicians in Britain. We are now beginning to get at the basal factors involved, and it would seem on the basis of current experimental evidence that the depth at which the seeds are planted is one of the most important of those factors. In the districts of assured summer rainfall, broadcasting the seeds and covering with light harrows to a depth of about 0·25 inch to 0·5 inch will, in most seasons, give an assured take of seeds (Williams, 1922). In the lower rainfall belts, however, this procedure results in a large proportion of indifferent takes, together with an undue proportion of complete failures. Drilling the seeds in the spring and placing them well into the soil moisture to a depth of about one inch, however, results in far fewer failures in the dry areas, and has proved reasonably effective in high-rainfall conditions also. In the latter case, however, drilling seems to have little advantage over broadcasting the seed. It has the grave disadvantage of leaving the wide bare spaces between the drills which, under many systems of after-management, do not close up quickly enough, thus permitting various weeds to gain rapid entry into the young developing sward. These disadvantages of drilling are, of course, equally apparent in low rainfall districts, but they can be overcome by specific methods of management. For example, the drills will close up reasonably quickly if the mixture contains wild white clover and the young sward is grazed closely during the first 12 to 18 months of its life. The use of special grass and clover seed drills with seed coulters 3·5 to 4 inches apart will also help in overcoming these disadvantages, and particularly where the subsequent management is such as to promote the rapid spread of white clover.

The evidence shows that deep planting is desirable in spring, and particularly in districts of low summer rainfall. The seed has to be placed at such a depth that it is in direct contact with the reserves of soil moisture. Germination and establishment of the ley are not then dependent entirely upon the incidence of an erratic summer rainfall. Further investigations dealing with these matters are in progress at the Grassland Improvement Station, Dodwell. It is by no means certain that autumn sowings need be placed as deeply as those made in the spring. Sowings made in autumn are much more likely to receive copious rainfall, and may, therefore, prove to be better when sown at depths of 0·25 inch to 0·5 inch rather than 1 inch or more. Shallow sowings are likely to come through the ground quicker than deep sowings, so long as the topsoil is moist enough for germination to take place. It is essential to get the plant away quickly, especially from autumn-sown seeds, where it is important that the plants are well-rooted and robust before the onset of winter conditions. The legume in particular must be well-established before winter, as otherwise it will be winter-killed. More research is necessary into all these problems, though we are fast reaching the stage in England when, by the adoption of a number of simple rules, bad and indifferent takes of seed need never occur.

Time of sowing

Time of sowing is another matter around which controversy has raged for many a decade. The research of the past twenty years, though by no means conclusive, has carried us some way towards a solution of the problems involved. So far as present information goes, it would seem that early spring is the best time for sowing, but that early autumn is a close second. In the " above 30 inch " rainfall belt of the west and north, the seeds mixture can be sown at almost any time between mid-March and mid-August. The summer rainfall in these districts is normally assured, and, with reasonably good precautions as to cultivations, manuring and subsequent management, good takes of seed are also assured during the summer months. Tilth and weather conditions are generally such as to make sowings impossible earlier than March, and normally the clovers do not establish from sowings made later than August. Even in the high rainfall west country, however, bad takes are not infrequent after sowings made in late May and June. This is most frequently true in dry seasons, when prolonged rainless periods may occur during the early part of the summer. In the " below 30 inch " annual rainfall belt of east and southern England, the best sowing dates are limited in most years to early spring (March and early April) and late summer (mid-July to mid-August). Sowings made from mid-March to mid-April in these districts can be uniformly successful so long as (*a*) the tilth is good, (*b*) the seeds are planted deep enough to be in the moist layers of soil * and (*c*) no undue smother is effected by the cover crop, *e.g.* cereals that may be employed. Seed sown in late summer over the date range mid-July to mid-August is normally also successful except in seasons when dry weather conditions persist into late autumn. In years when the autumn weather is mild, sowings of the grass-legume mixture made as late as the first week of September may be highly successful, but these late sowings are accompanied by hazards that are largely obviated by sowing earlier. It is the clover constituents that most easily fail after sowing too late.

The grasses have a longer sowing season, and highly successful takes are achieved in ryegrass (both Italian and perennial), cocksfoot and timothy when sown in September or October, and even in November. Current experiments conducted (1940-43) by the Grassland Improvement Station have indicated that these grasses can be sown under winter corn as late as the end of November, and still lead to a fair take of seeds which will develop into a reasonable sward if grazed properly after the removal of the corn crop in the following season. The clovers do not, however, establish after such late sowings, and one of the problems that needs investigation is to discover how best to establish the leguminous part of the seeds mixture in the already established grass sward. Once we know the appropriate technique of doing this, we have at our disposal another method of establishing the complete ley—a method that might prove useful on some of our more obstinate clay soils in the Midlands and eastern districts of England.

* About one inch deep seems generally to be safe. On certain soils there is evidence to suggest that 1·5 inches is a safer depth—it is likely that the seeds need to be planted at such a depth as to be in direct contact with " permanent " soil moisture.

Rate of seeding

This aspect will be dealt with in the section on seeds mixtures, though one or two important points should be made here. The traditional seeding rates in Britain have been of the following order :—

Short-term leys (1 to 2 years). A total seed rate of 15 to 25 lb. per acre, using largely the ryegrasses and the clovers (chiefly red clover).

Long-term leys (3 years and upwards). A total seeding of 25 to 40 lb. per acre, using a wide variety of both grasses and legumes.

In recent years, when more thought has been given to matters relating to the ley, very successful long-duration swards have been made after using much reduced seed rates. For example, excellent leys have been produced at Wye Agricultural College and elsewhere in south-east England using a mixture of 14 lb. Kentish ryegrass and 2 to 3 lb. Kentish white clover per acre. More recently, the seed-growing counties have employed a mixture consisting of only 6 lb. per acre S.23 perennial ryegrass with 3 lb. S.100 white clover, and first-class long-duration leys with an excellent balance of grass and legume have been the outcome. The whole matter of seed rates, therefore, needs to be more critically investigated. The problem is closely related to the question of simplification of the seeds mixture as well as to the employment of special-purpose mixtures based on the new leafy strains of both grasses and clovers now being made available in commercial quantities.

Sowing with or without a cover crop

Sowing the seeds mixture under a cover crop, usually a cereal, has been the more or less accepted method throughout Britain. This procedure arose as a natural sequence of the introduction of the one-year clover ley introduced into East Anglia from the Netherlands to replace the bare fallow of earlier days. When the one-year ley is sown in the corn, there is no loss of time during which the land lies idle. Also, when the short ley is based on ryegrass and red clover (as is normal) the take of seeds of these robustly-establishing species is normally good, unless the corn is badly lodged. In the case of long-duration leys, however, the retarding influence of the cover crop, and especially of cereals grown for their grain, is much more pronounced. The constituent species and/or strains of grass and legume employed in the long ley are normally slower to establish than those of the ryegrass *cum* broad red clover of the short ley. If the retarding influence of the cover crop be added to this, it becomes obvious that the long ley, when sown under corn, may never develop at all, or at least the adverse effect upon the more persistent elements in the mixture will be great enough markedly to affect the persistency of the ley as well as its initial productivity. For these reasons, and from experience gained in the course of experimental work throughout Britain, it has become obvious that the best and safest method of establishing the long-duration ley is either to sow without a cover crop of any kind or to undersow in a cereal or other crop (such as rape or Italian ryegrass) which will be *grazed* from the outset and as soon as feed becomes available on it.

The point which has been established is that the cover crop does harm,

unless it is itself used for grazing while the young seeds are becoming established. Whether or not it pays in any particular circumstance to sow out a long-duration seeds mixture under corn, with all its attendant risks of indifferent takes in the persistent elements, remains a matter for further study under a variety of local conditions.

What is already apparent in many districts is that farmers are probing for new methods designed to ensure better takes of seeds; among these the following are two examples :—

(i) sowing on the disced-up stubble immediately the corn has been harvested and grazing the young seeds that same autumn;

(ii) sowing only Italian ryegrass in the corn, grazing the stubble the same autumn, then either discing or shallow-ploughing and sowing the full long-duration mixture in the following spring and grazing the new ley throughout its seeding year.

Manures and Fertilizers

Maximum production in the ley, just as with every other crop, calls for the intelligent use of the manure bag in order (*a*) to make up initial deficiencies in the soil, and (*b*) to effect replacement of plant foods drawn out in the crop during the course of normal farming operations. Most soils in England tend to be deficient in phosphates, and this is particularly true of the old grasslands from which milk and bone has been removed for generations without adequate replacement. Except on the calcareous soils (Lower Lias, Oolite, Chalks and other limestone formations), the land of Britain is also lime-deficient. Potash is well supplied in many of our grassland districts, and the ley as such is not a crop that gives striking responses to potassium salts applied artificially. There are exceptions, however, especially on the chalk downs and valley gravel soils of southern England; on some of these soils the ley will not flourish unless potash is applied. Nitrogen gives large responses when applied to the ley, and has a particularly important place in the initial establishment of the seeds. Unduly heavy or too frequent dressings of soluble nitrogenous fertilizers have to be avoided, however, except where the soil fertility in terms of organic residues and minerals is already at a high level. In the establishment of the ley, therefore, throughout England, phosphates are of fundamental importance —in fact, the high-class ley with abundance of legume is hardly possible anywhere in this country without an adequate initial dressing of phosphatic manure. Equally and on most soils an initial dressing of lime is necessary for the full development of the ley. After the lime and phosphates have been put right, then nitrogen can be used more freely, not only to establish the grass-legume mixture, but also to maintain its production at specific seasons of the year, notably in late autumn and early spring.

The dressings in common usage in England are 1 to 2 cwt. per acre soluble nitrogenous fertilizer (sulphate of ammonia, nitro-chalk and nitrate of soda), 3 to 6 cwt. phosphatic manure (basic slag and superphosphate), 1 cwt. potash and 1 to 2 tons lime (as ground carbonate or as oxide).

Minor elements

There have been few reports in England of deficiencies due to minor elements in the herbage. In the south-west and west instances of cobalt-deficiency (Patterson, 1938) have been reported, whilst in Derbyshire copper-deficiencies (Dunlop, 1939; Wells, 1940) have occurred. Excess of molybdenum has been shown to be responsible for the "teart" (= excessive scouring) condition of dairy cattle in Somerset and elsewhere (Jealott's Hill, I.C.I., 1940) —a condition that has been corrected by special feeding of copper. Other deficiencies may come to light as further investigation takes place, but up to the present the sum total of minor element deficiencies in our leys has done little, so far as we know, to reduce the output derived from those leys.

Placement of fertilizers

Recent work, much of it evolved during the war years, indicates the desirability of placing the applied plant foods in the soil layers immediately in contact with the seeds. Experiments in the use of the combine drill (where seeds and manure go together into the same soil layer) tend to show a marked advantage in the initial take and growth of the seeds mixture when compared with plots on which the fertilizer is broadcast. Under wartime conditions the advantage has been greater because of the smaller available supplies of phosphates and the fact that reduced dressings could be used successfully where combine-drilled as against broadcast. There is also preliminary evidence which suggests that phosphates combine-drilled do not revert so rapidly in the soil; a larger proportion of the applied phosphate therefore becomes available for the immediate use of the growing plant.

Seeds Mixtures

Historical

Some of the earliest records in Britain of specific mixtures used for the production of leys occur in the seventeenth century, when lucerne, sainfoin and red clover were employed both singly and in admixtures (Worlidge, 1669; Fussel, 1934-35). Wild white clover is recorded as having been used as early as 1707 (McGill and Smith, 1925). During the eighteenth century, simple mixtures of ryegrass, white clover and trefoil were being used by a few pioneering landowners and farmers. In the course of the nineteenth century and following upon the work of Sinclair (1816) and others, a greater variety of species was being used in the grass-legume mixture, until by the close of that century mixtures of great complexity were widely advocated. At the close of the century, Robert Elliot, perhaps the first advocate of ley farming in the modern sense, published his classical work (Elliot, 1898 and 1943). Elliot also advocated the complex mixture, and laid particular emphasis on the value of including the deep-rooted herbs. Among these were chicory, yarrow, burnet, sheep's parsley, ribgrass and wild parsnip, together with a wide variety of leguminous plants, the clovers, lucerne and kidney vetch.

At the opening of the present century Gilchrist was at Cockle Park, and his standard mixtures marked a great step forward in the simplification of prescriptions. The Gilchrist mixtures advocated forty years ago have had a

profound influence upon British ley farming. Not only did Gilchrist use relatively simple mixtures containing chiefly ryegrass, cocksfoot, timothy and the clovers, but he was the first to lay real stress upon strain in herbage plants. He laid great stress on the use of wild white clover, and advocated the use of New Zealand cocksfoot, a type we now know to represent a reasonably leafy and persistent product. He also stressed the value of late-flowering red clover. There is little doubt that the value of Gilchrist's teachings and the wide success of his mixtures throughout Britain were, in large measure, linked with the use of the leafy and persistent clovers and of leafy cocksfoot.

Subsequent to Gilchrist's day, the trend in seeds mixtures has been towards a further simplification of prescriptions, and the present-day trends are towards mixtures of one grass with one (or two) legumes, with special emphasis on the use of mixtures designed for particular purposes. One of the most far-reaching developments of seeds mixture work during the past two decades has been that opened up by the plant breeder. In this country that work has been developed by Stapledon and his colleagues at Aberystwyth. The outcome of the plant breeder's work is destined to have a profound influence upon the whole question of compounding seeds mixtures. While the general tendency towards employing simple one grass plus one clover special-purpose mixtures has been noted, the advent of the new varieties has enabled the agronomist to consider the value of a blend of strains. It is now, therefore, appropriate to think in terms of the simple one grass/one clover mixture as a blend of varieties of the grass plus a similar blending of the legume. Thus, to give an example, a simple mixture of 20 lb. ryegrass and 2 lb. white clover might (if based on bred strains) sensibly read as follows :—

	lb. per acre
Perennial ryegrass :	
certified S. 24—dense, early type.	10
certified S.101—dense, medium type	5
certified S. 23—dense, pasture type	5
White clover :	
certified S.100—dense, early type.	1
certified S.184—dense, " wild " type	1
	22

Such a mixture as the above has proved, in fact, eminently suited for the production of first-rate long-duration grazing leys, especially on fertile lands.

General-purpose mixtures

As has been inferred above, the trend in England is now towards using mixtures designed for special purposes, although the general-purpose mixtures from which hay or grazing may be taken are still in very general usage throughout the country. A very wide range of general-purpose mixtures is employed, and it would be quite inappropriate to list even a fraction of these in this place. The large majority of these mixtures are modifications in one form or another of Gilchrist's original Cockle Park mixture. The following is an example, and one which has given highly successful results, especially where leafy strains form a part of the mixture :—

	lb. per acre
Italian ryegrass	5
Perennial ryegrass	16
Cocksfoot	8
Timothy	4
Broad red clover	2
Late-flowering red clover	2
Wild white clover	1
	38

Special-purpose mixtures

A. *Pioneer leys.* These are used chiefly on soils of low fertility and during the first stages of reclamation. They consist chiefly of fast-growing, short-lived plants able to provide quick feed, which is grazed off *in situ* with a view rapidly to promote soil condition to the standard necessary to grow either corn crops or a high-class ley. Various combinations have been employed, among the most successful of which have been (*a*) rye and Italian ryegrass, and (*b*) Italian ryegrass with rape and hardy green turnips. Sometimes broad red clover, alsike or trefoil is added to these mixtures.

B. *Short leys* (1 to 2 years). These in Britain are based mainly on ryegrass, red clover and trefoil. If the ley is to be left down for a second year, at least a part of the clover will be in terms of late-flowering red, and, perhaps, alsike clover and white clover will be added to the mixture. The one-year ley is almost everywhere a hay ley, and forms an integral part of the traditional rotations of English farming. The precise mixture used varies widely: a common prescription is as follows:—

	lb. per acre
Italian ryegrass	5
Perennial ryegrass	10
Red clover	8
	23

In many districts, especially in eastern England, the clover is increased to 10 lb. and even 14 lb. per acre, and the seeding of ryegrasses reduced, or ryegrass will often be omitted. In parts of the East Riding of Yorkshire and on the Wolds of Lincolnshire, an all-legume mixture is frequently used; a typical prescription would be:—

	lb. per acre
Red clover	6
White clover	4
Alsike clover	4
Trefoil	4
	18

To this mixture may sometimes be added 4 lb. ribgrass and sometimes 5 lb. perennial ryegrass. The ley is sown under corn, the stubble is grazed in the autumn after corn harvest, and the ley is grazed again throughout the first harvest year. It is essentially designed to promote the rapid upbuilding of fertility through the legume and through the grazing animal. The omission of ryegrass has as its object the control of frit-fly (*Oscinella frit*) and take-all (*Ophiobolus graminis*). Ryegrass is known to harbour both these pests.

An alternative one-year hay ley which has been used and which provides excellent leafy and nutritious crops and good aftermath grazing is as follows :—

	lb. per acre
Timothy	14
Late-flowering red clover	5
	19

Garrett (1941) maintains that timothy does not carry take-all to the same extent as do the ryegrasses. The timothy/red clover combination results in very heavy crops of hay coming to maturity rather later in the season than the ryegrass/clover ley.

In parts of Wiltshire, ryegrass and S.100 white clover are being used as a one-year hay *cum* grazing ley. The mixture used may be as follows :—

	lb. per acre
Perennial ryegrass	10
S.100 white clover	4
	14

This is a good " fertility-building " ley, and depends for its success on the rapid development of the robust S.100 white clover. To ensure success, the seed rate of white clover should be high ; in general, it may be said that where white clover is used in the mixture, the shorter the term of the ley, the heavier should be the seed rate of the white clover.

C. *Long-duration leys* (3 years and upwards)

(*a*) *Hay leys*. Long-duration hay leys from which hay is taken over a succession of 3 to 5 years and where grazing is no more than incidental, resolve themselves as follows :—

Sainfoin leys. Sainfoin has been used widely on the calcareous soils of southern and eastern England, chiefly as mono-plantings. The old English (common) sainfoins persist well until about the fifth year, but when sown alone without companion plants the sainfoin ley quickly runs into a very weedy condition. Pure sainfoin leys in their third to fifth years are a feature of many a landscape because of their weediness—many of them are veritable botanical gardens, notable for the variety of their flora. More recently it has been shown that sainfoin used in a mixture with appropriate companion plants maintains its valuable features and remains reasonably free from weeds. The type of mixture which is showing itself to be appropriate is as follows :—

	lb. per acre
Common sainfoin	40*
S.123 or Montgomery red clover	3
S.100 white clover	1
S.48 or S.51 timothy	6
	50

* 40 lb. per acre *milled* seed, equal to about 70-80 lb. per acre of seed in the husk (unmilled).

Lucerne leys. Lucerne is a plant that has for long been grown in Britain, but has never been fully exploited. Current research is indicating that we have in lucerne a most valuable hay plant, and one of inestimable value on the dairy farm, particularly in drought. The drawback of mono-plantings of lucerne is the cost of keeping them weed-free. With lucerne as with sainfoin, the appropriate companion plants need to be employed. Mixtures of cocksfoot with lucerne have, in recent years, shown themselves to be satisfactory. Cocksfoot, however, tends to be suppressive, particularly under continued hay conditions. It may, therefore, be proved that either timothy or meadow fescue (or both) are better companion plants to accompany lucerne. The following are typical suggested mixtures :—

	lb. per acre
Cocksfoot with lucerne :	
Cocksfoot S.37 or S.204	6
Lucerne	25
	31
Timothy with lucerne :	
S.48 or S.51 timothy	6
Lucerne	20
	26
Meadow fescue with lucerne :	
Meadow fescue S.53 or S.215	10
Lucerne	20
	30

It remains to be seen whether there is any advantage in sowing late flowering red clover and/or S.100 white clover as additions to these lucerne mixtures. Trials along these and other lines are now in progress at the Grassland Improvement Station and elsewhere in England.

Leys based on timothy and/or meadow fescue with clover. The leafy strains of both timothy and meadow fescue make excellent hay plants, providing leafy herbage and heavy yields of hay. The following mixture is typical :—

	lb. per acre
S.48 or S.51 timothy	10
S.53 or S.215 meadow fescue	10
S.123 or Montgomery red clover	4
S.100 or New Zealand white clover	1
	25

(*b*) *Grazing leys.* The ryegrass/white clover sward provides a first-class, long duration grazing ley, either for the production of meat or milk. Its usefulness has been well-stressed for conditions all over the country, and the sward is particularly valuable for the better classes of soil. Under high rainfall

conditions (*i.e.* the "above 30 inches" belt) and on good soils, the ryegrass—white clover ley fulfils most of the demands of the grazier and dairyman. A typical mixture is as shown on p. 12, but to which may be added, say 5 lb. Italian ryegrass and 2 to 3 lb. late-flowering red clover, preferably S.123 or Montgomery red. The most relevant criticism of the ryegrass-clover ley is that under severe drought conditions such as are experienced in the drier districts of England during the months of July and August, ryegrass may stop growth entirely and the ley become temporarily unproductive. For this reason there is a strong case for other mixtures designed specifically to cater for the periods of summer drought. The basal grass in these will normally be leafy cocksfoot, although it must clearly be understood that many (if not all) of the hay mixtures quoted above will, during their aftermath period, materially help to cater for the dry weather of July and August. A typical prescription for a cocksfoot mixture designed specifically for providing abundant feed in summer drought would be :—

	lb. per acre
Leafy cocksfoot (S.37, S.26, S.143 or New Zealand)	14
Late-flowering red clover (S.123 or Montgomery)	3
White clover (S.100 or New Zealand)	1
Leafy perennial ryegrass (S.23 or S.101)	4
	22

To provide for maximum keep in July and August the cocksfoot ley should be rested for the whole of the month of May, at the end of which it can be cut as leafy hay or silage. It can be further rested during the whole of June, followed by hard grazing during July and August. This same mixture, if rested from September onwards (and preferably dressed with nitrogen in early September), will provide the earliest spring bite during the February-March period. It has, therefore, a two-fold function : namely, to cater (*a*) for summer drought, and (*b*) for grazing very early in the spring.

Management

General

One of the major functions of the ley is to provide an abundance of nutritious feed for the grazing animal. In order to fulfil this function, the sward makes certain fundamental demands on its environment. The fulfilment of these demands is quite appreciably under the control of the farmer, and may be discussed under the general heading of *grassland management*. To function at its maximum efficiency, the ley requires to be managed along certain definite (though not yet fully defined) lines. Sometimes these requirements do not accord with the demands of the herds and flocks on the farm. The farmer himself then has to decide whether to mismanage his grass for a temporary period or whether to look for other crops in order to fulfil the requirements of his stock. Alternatively, he may decide to increase or reduce his stock by buying or selling respectively, or, again, he may agist stock to or from other lands. These decisions must always be left to the farmer himself. To meet such eventualities, which in farming practice are in fact day-to-day events, the agronomist must bear fully in mind the fact that a ley which is

capable of tolerating temporary ill-management and further capable of rapid recovery from the effects of such management is by so much the more valuable to the stockmaster. This is a major argument in favour of the ultra-simple (one grass plus one legume) mixture, for not only can superb swards be established relatively quickly, but, when established, the simple mixture provides a sward that is singularly fool-proof as regards management and maintenance. It is not possible in practice to be tied down within narrow margins relative to grassland management, particularly having regard to the well-being of all the leys on the farm. There must be flexibility all along the line, simply because growth will ultimately bear a close relationship to weather conditions, and these are largely unpredictable. The aim of the agronomist should therefore be to make suggestions whereby leys of different types, each designed for special purposes, are laid down on different fields on the farm. These leys should be reasonably fool-proof and capable at short notice of being employed to fulfil immediate or critical needs on the farm while at the same time retaining their vigour and full potentialities to fulfil the prime purpose for which they were initially designed.

Management in the seeding year

The ley *is a crop* in the full sense of the term as used in agricultural matters. In order to provide for the full development of this crop, everything should be done to establish it properly. During the establishing period of the ley, therefore, management must be such as to favour a good take of seeds. If necessary, and for the period of establishment, the stock must be subservient to the ley. Once the ley is fully established (usually in about 12 months after sowing under English conditions), it then becomes subservient to the stock within the general broad principles of good grassland management and utilization.

(*a*) *Sowing under a cover crop* (*mature grain*). Most seeds mixtures in this country are still undersown in the corn. Frequently the seeds are sown under spring corn (oats, barley or wheat) and the most satisfactory takes follow if corn and seeds are sown at the same time or the seeds at least within a day or two of corn-sowing. Take of seeds suffers materially if sowing is delayed until the corn is well established. There are at least three major reasons for this comparative failure of the seeds, namely, (1) the seeds mixture is sown too late in the spring ; (2) the tilth conditions are not at their best, and the seed is not planted deep enough, and (3) the already established corn crop exerts an undue smothering influence upon the young seedlings as they develop. Extreme etiolation, therefore, often results.

Seeds are frequently also sown in the spring under autumn-sown corn (wheat or oats). Where good standing varieties are used the risk of devastation by lodged corn is largely reduced ; the most frequent cause of failure is due to lack of a good tilth. Much of our wheat land in England tends to " cement " badly on the surface, and it is not easy to prepare a fine seed bed for seeds in the early spring. The established wheat crop is able to stand much rough harrowing and rolling in spring. To make a real tilth for the grass-legume mixture requires excessive surface cultivations in the spring. Wheat (autumn-sown) will stand up to the necessary spring cultivations and

may even derive benefit from them. Winter oats, however, are not favoured, and may even be unduly harmed by too drastic harrowings. Wheat, therefore, is a better cover crop than winter oats, simply because better spring tilths are possible in practice.

Whether sown under winter or spring corn, it is best to sow early in the spring and to employ a good standing variety in order to minimize the risk of lodged corn, which always unduly damages the young seeds. Most important of all, however [and this is of special importance in the case of the long-duration (3 years plus) leys], is to commence grazing as soon as the corn has been harvested. This stubble-grazing greatly assists establishment by consolidation of the surface soil, by providing the seedlings with a firmer roothold and also by promoting tiller production in the grasses. Young swards should not in general be grazed too late into the autumn, but the topsoil should be left well-consolidated after the stock have been over it and the whole field left in an evenly-grazed condition, so that there is no danger of " winter proudness." *

(*b*) *Sowing under a cover crop* (*silage mixtures*). Much the same principles hold here as in the case of the mature grain crop, except, of course, that the silage crop is removed at a much earlier date, and therefore does correspondingly less harm to the general " take " of seeds. This method has been fairly widely adopted and has on the whole been successful. Again, it is important to bring the grazing animal to bear on the young seeds as soon as the cover crop of silage is removed. Normally, such a crop would be harvested in June or early July, and the new ley would be grazed from then until the end of October, by which time it is often fully established.

(*c*) *Sowing under a cover crop* (*cereal or rape used for grazing*). This method has been widely employed in the hilly districts of the west and south-west of England and Wales. In North Devon, for example, the sowing of the long-duration ley under rape has been practised for a long time. More recently, pioneer farmers and others have sown their mixtures under a light seeding of oats or barley, which is designed to provide immediate grazing. This latter procedure is largely in its experimental stage, but the indications are that it can be highly successful, particularly under conditions where the establishment of the ley presents difficulty. In general, the take of seeds is good when sown under rape or a grazing cereal so long as grazing starts early enough and the cover crop has no smothering effect on the developing seeds mixture. It offers a means of providing green feed quickly, and the land is hardly out of action at all. More experiments, however, are required, particularly regarding the appropriate variety of cereal and the seed rates at which it should be sown, and this in relation to the date when stock are first given access to the new ley. From preliminary evidence collected at the Grassland Improvement Station, it would seem that the Welsh 4 to 6-rowed barley (Haidd Garw) makes a very appropriate grazing cereal, and because of its high tillering capacity may possibly be sown at quite low seed rates (20 to 25 lb. per acre) for this special purpose. Under these conditions it should be possible to graze the new ley (and

* A term used to denote excessive leafy, succulent growth made during a mild autumn, a condition which seems to be unduly harmful to young leys. The condition is largely overcome by appropriate grazing during autumn.

to provide real feed) in about 3 to 4 weeks after sowing. Cereal and seeds would, of course, be sown together as part of the same mixture.

(*d*) *Sowing without a cover crop* (*or with Italian ryegrass*). Sowing the grass-legume mixture without a cover crop (with or without Italian ryegrass) provides a means for getting the stock on the young developing seeds at the first available opportunity. The agronomic work done at Aberystwyth, together with more recent experiments throughout England, have shown that excellent swards can be established quickly by this means. Within a year of sowing, such swards closely approach the form of a mature ley, and are in full production. The hazards of poor takes are reduced to the minimum, and will no doubt be further reduced as fresh knowledge is accumulated. The chief disadvantage of the method has been the time-lag between date of sowing and date of first grazing. This period ranges from about 5 to 12 weeks, although recent evidence tends to show that even where initial establishment is slow, benefit accrues by bringing stock to bear on the young ley not later than in the sixth week after sowing. Under such conditions the benefit of employing a fast-growing (grazing) cereal is obvious in that it provides feed to which the stock are drawn. The result is a more uniform treading and urination all over the field, all of which speeds up the rate of establishment in the grass-legume mixture. The best results from the viewpoint of rapid and full establishment of the young ley are obtained by (1) bringing in the grazing animal at the first opportunity ; (2) using as heavy a concentration of stock as is available to eat off the herbage in the shortest possible time ; (3) resting the field completely for 10 to 14 days and repeating the process of graze and rest until the end of the first season, when the new ley should be more or less fully established.

Sometimes it is desirable further to assist consolidation of the topsoil by the frequent use of the heavy smooth roller drawn behind a tractor, which should be kept in low gear. Weeds and other roughage will often invade the young developing ley and may even get away ahead of the sown seeds. In these circumstances, the mowing machine is used freely to cut down weeds and roughage. If such mowing-over be done while the animals are in the field, the majority of the weeds are eaten in a semi-wilted condition by the livestock. Sheep, cattle and horses have at various times been used satisfactorily for these first grazings. Provided good control of the grazing is ensured, there does not appear to be any fundamental reason why all classes of domestic grazing animals should not be employed for the purpose of establishing the new leys.

Management in the first harvest year and subsequently

The most common procedure in the first harvest year is to take hay. This is satisfactory enough in the case of the hay leys (short-term and long-duration), but where the ultimate aim is first-class pasturage in which white clover and the leafy grasses should predominate, the practice of taking heavy hay crops in the first harvest year is to be deprecated. This is particularly true where the long-duration ley is sown out under corn and where (as frequently happens) hay is taken again in the second and third harvest years ; the ley is then largely spoilt as a high-production unit. Two or three hay crops are, however, still too frequently taken in the first harvest years of the long-duration ley in

this country. In recent years, technical officers in the English counties have by educational channels made an effort to dissuade farmers from taking hay crops from their first-year swards. This teaching is already beginning to take effect, and an increasing number of general-purpose leys are being grazed during their first harvest year.

The best management on the grazing ley in order to maintain both productivity and persistency is to graze and rest on a systematic and rotational system. Different grass/legume mixtures will demand rest periods of differing lengths. Thus the evidence available to us suggests that the ryegrass/white clover complex is at its best under fertile soil conditions, and where the rest period between grazings is of the order of 10 to 14 days during the summer growing period. The fully established cocksfoot-clover ley probably requires a longer rest period (perhaps 20 to 25 days) in order to give its maximum production of nutrients (see Aberystwyth, 1939*b*). These matters await further investigation, but it is reasonable to suppose that each class of ley based on grasses with different ecological demands will correspondingly require their own characteristic variations in management.

Special-purpose leys designed to produce feed at specific periods of the year should be managed in such a manner that they produce their maximum at those special times. Thus the cocksfoot-with-clover ley, the purpose of which is to produce feed during the dry weather of July and August, must be completely rested in May (with possibly a silage cut) and again in June. The ryegrass or timothy or cocksfoot ley, the chief purpose of which is to provide late autumn (November-December) grazing, will probably need to be rotationally grazed during the summer, but should be completely rested from mid-August onwards until it is required in the autumn. Similarly, a cocksfoot ley with the chief function of providing grazing in January, February or March needs to be rested from early September (when it would be given a dressing of soluble nitrogen) until such time in the early spring as it may be required.

These are the general lines along which our agronomic work has taken us in Britain. Our existing knowledge is still meagre at many points, and further detailed trials and investigations are necessary if we are to progress. One thing seems certain, namely, that with the proper exploitation of the ley as the pivotal crop in any system of ley farming, we have at our disposal a most potent instrument. An instrument which, if sensibly used, will promote in British agriculture not only a new interest in, but new standards of productivity and of fertility in our soils.

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Introduction

General

Wales, including Monmouthshire, has a total land surface of approximately 8000 square miles, of which the total agricultural area in 1939 (Ashby and Evans, 1944) was about 7000 square miles. Since the outbreak of the Second World War a considerable acreage has been lost to agriculture, at least temporarily.

The lowlands, largely of an undulating nature, consist of a narrow fringe on the western sea-board and wider areas at points on the north and south coasts. The rivers which, in their upper reaches, flow eastwards and then turn north or south to the sea, such as the Dee, Severn, Wye and Usk, form relatively extensive valley bottoms of fertile land. The Towy flowing more or less southwards and the Clwyd flowing northwards also pass through relatively broad fertile land, particularly in their lower reaches. The rivers on the west are usually short and rapid flowing and the valleys are deep and narrow so that there is proportionately less good land. The lowlands enclose a central upland to mountain massif stretching from Snowdonia in the north to the Brecknock Beacons in the south, with outliers in different directions, such as the Rivals in Caernarvonshire and the Prescelly in Pembrokeshire. The highest peaks, over 3000 feet above sea-level, are found in the Snowdon range. Although the cultivated land is found mainly in the valleys, there is evidence that it has from time to time extended well up into the foothills of the mountains.

Geology and soil

Geologically the greater part of Wales is formed of hard non-calcareous Palæozoic rocks and their associated drifts. Old Red Sandstone (Devonian) and Carboniferous rocks (including Carboniferous Limestone) occur in the south and north-east. Igneous rocks occur in the north-west and metamorphic (Precambrian) rocks are found in Anglesey. Triassic and later rocks occupy a small area. Recent alluvium and coastal sands are widespread but generally of comparatively small extent. The soils show all transitions from free drainage to highly impeded drainage, the latter occurring extensively in the north-west and west. On account of the hardness of the rocks the soils are usually shallow and stony, with deeper accumulations at the foot of slopes and in hollows (Robinson, 1937). Most Welsh pastures are situated on soils with a low natural content of phosphate and lime, but they are generally fairly well supplied with potash and nitrogen.

Climate and rainfall

The climate is mild and humid. The rainfall, which is fairly well distributed through the growing season, varies from less than 50 inches on the lowlands, to from 50 to 80 inches on the uplands, and considerably more than 80 inches on some of the higher mountains, especially in Snowdonia. In some coastal areas and in some districts on the eastern border the rainfall is as low as 30 to 35 inches per annum. The moorlands and mountains are

often cloud-covered and misty, with reduced evaporation at a time when the lowlands enjoy sunshine.

The daily range of temperature is small. Even in winter long periods of frost and snow are rare on the lowlands. The upland climate is more severe and snow may persist for some time on the mountains in winter. The warm air of the Atlantic and the prevalence of winds from the west bring the effects of the warmth of the sea for some distance inland (Bowen, 1941).

Vegetation

It is probable that the primeval vegetation over the greater part of Wales, at least below 1500 feet, was deciduous forest. There is no apparent evidence of coniferous forests. The lowlands were largely oak, while the uplands were largely birch forest. Woody remains of trees such as birch, hazel and oak are to be found on peat even at 1500 feet and higher.

In 1935 (Stapledon *et al.*, 1936) rough and hill grazings occupied about 38 per cent of the agricultural area, the main associations being roughly as follows :—*Molinia* and *Nardus* moorland (17 per cent), mountain fescue and fescue-*Agrostis* (10 per cent), heather moor (4 per cent) and dense bracken fern (3 per cent). Other scattered but smaller associations included wet lowland bog, dense gorse, lowland heaths including estuarine saltings and sand dunes, *Agrostis* with rushes and cotton grass and deer grass moors.

Livestock and land utilization

The climate makes the country eminently suitable for grassland husbandry and the raising of livestock. Hay and pasture are the main crops, and, as already stated, there is a high percentage of land in " rough grazings." Oats is the chief cereal, while forage crops such as broadcast rape, turnips, and, to a lesser extent, kale, are extensively grown. Potatoes and drilled root crops —swedes, turnips and mangolds—are the main cleaning crops in the rotation.

Previous to the outbreak of the Second World War there was a considerable increase in grassland dairy farming with a decline in the acreage of grain crops. During recent years and on account of the war, the increased area of cultivated land has stimulated home-grown production very considerably, as thousands of acres of old worn-out grassland have been cropped, cleaned and regrassed. During the period from 1939 to 1944, the total cattle numbers have increased by approximately 9 per cent (80,000 head) and the dairy cattle by about 18 per cent. The sheep population during the same period has decreased by about 15 per cent (700,000 head) ; sheep numbers are, however, again recovering. There has been a substantial fall in the pig and poultry population. Since the last century, on account of changes in public demand and taste, cattle, wethers and ponies have practically disappeared from the " open hill," and their place has been taken by sheep of younger age, mainly female breeding stock. The custom of keeping 3 to 4-year-old wethers has more or less died out—the demand is for small joints, lamb rather than mutton, and " baby beef " rather than mature beef. As a result of the change-over the hill grazings have deteriorated, due partly to understocking and to the absence of heavy stock, and roughage on the higher land and bracken on

the less exposed ground have increased on large areas. In order to encourage the return of cattle to these hill grazings, the Government at present gives a grant-in-aid for cattle maintained entirely under these conditions for 5 months of the year.

Whereas in normal times the cultivated land on most of the coastal areas does not extend much beyond the 800 feet contour, in mid-eastern Wales there are extensive areas of rotation land above the 900 to 1000 feet contour. Although the soils of the country as a whole are somewhat shallow, particularly on the slopes, there is fairly deep soil on much of the valley land, while even above the 1000 feet contour there are relatively deep, free working soils on large areas in parts of mid-Wales and the eastern border.

Establishment and Competition

Before good pastures can be produced from sown grass and clover seeds the establishment of a sufficient number of robust plants per unit of area is essential. The number of seedlings produced in the field from every hundred seed sown is, for practical purposes, much lower than in the laboratory. Different species and strains within species possess different inherent powers of establishment under field conditions. A considerable body of evidence is available to show that there is a positive correlation between percentage establishment * and grain weight (= weight of 1000 seeds). When sown in pure cultures most of the larger seeded species and strains give a higher percentage figure for early establishment than smaller seeded species and strains, both under garden and field conditions. The same is true, with certain reservations, when different species and/or strains are sown together as mixtures (Aberystwyth, 1927). Some species and/or strains are poor competitors in mixtures, at least in the early stages of sward formation, while others are aggressive irrespective of systems of management. Others again are sensitive to management; they may be aggressive under grazing conditions but poor competitors under hay conditions. Meadow fescue serves as an example, under Welsh conditions, of a species which is very sensitive to competition in mixtures containing also the ryegrasses and red clover, despite the fact that it has a large seed relative to most grass species used in mixtures. In competitive mixtures on Welsh soils the ryegrasses are aggressive to most species in the seeding and first harvest years. Cocksfoot under most conditions in mixtures also containing the ryegrasses does not generally compete well in the first year except when sown as the dominant species. Its ability to compete at this stage depends largely on the vigour and seed rate of the associated species. On relatively fertile lowland conditions, winter grazing in the seeding year and spring grazing in the first year are generally lenient, a system of management which suits the growth of both Italian ryegrass and hay strains of perennial ryegrass. Severe and prolonged spring grazing, on the other hand, prevents their recovery materially and quickly; such hard grazing also affects red clover, particularly the early varieties which are low tillering in comparison with late varieties. Establishment is thus closely linked

* "Percentage establishment" is an expression of the number of plants produced in the field from every 100 viable seeds sown.

Fig. 2.—Cardiganshire—Welsh black cattle on improved hill pasture (1100 ft.), Cahn Hill Improvement Scheme. (Photo Abery, Builth. Courtesy *Farmer and Stockbreeder*.)

Fig. 3.—Cardiganshire—Welsh mountain lambs grazing a pioneer crop of broadcast rape and turnips (1300 ft.), Cahn Hill Improvement Scheme. (Photo Abery, Builth. Courtesy *Farmer and Stockbreeder*.)

Fig. 4.—Cardiganshire—Derelict lowland field dominated by scrub. Ground herbage largely *Agrostis* spp., *Molinia*, and *Nardus*. Photo Aug. 1939. (Courtesy Principal Ifor L. Evans.)

Fig. 5.—Cardiganshire—Photo (Nov. 1941) of Fig. 4 (above) after improvement by clearing, ploughing, etc., and reseeding direct. Sward in foreground 16 months old. (Courtesy *Farmer and Stockbreeder*.)

Fig. 6. — Breconshire — Background : Typical derelict hill country (1000-1300 ft.) ; encroachment by bracken and scrub. Foreground : Direct reseeding under rape ; sward 1 year old (1000 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 7. Breconshire—Direct reseeding as private enterprise; broadcasting seed and covering (1000 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 8. Breconshire—Direct reseeding as private enterprise grazing 6-weeks' old pasture (800 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 9. Breconshire—Close-up photograph of Fig. 8 on same date. (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 10. Breconshire—Direct reseeding as private enterprise: Hereford cattle grazing on 5-year-old pasture (1100-1200 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 11.—Breconshire—Close-up photo of rape undersown with grass and clover seeds after rotation of turnips, followed by oats (1100 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 12. Breconshire—Ploughing dense bracken on fairly deep soil (1000-1100 ft.). (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 13. Breconshire— Foreground : Broadcast crop of rape and turnips (80-acre block) being 2nd stage in reclamation of land of type in Fig. 12 (1000-1100 ft.). Background : Open hill rough grazing with scrub. (Photo Thompson, Cardiff. Courtesy Brecon. W.A.E.C.)

Fig. 14.—Breconshire—3rd stage in reclamation of land of type in Fig. 12 : potatoes (120-acre block) following rape and turnips (1000-1100 ft.). Non-flowering strip across middle background due to absence of lime ; under these acid conditions, lime is valuable for potato crop. (Courtesy D. Walters Davies.)

Fig. 15. Radnorshire 4th stage in reclamation of land of type in Fig. 12. Cereals undersown with grass and clover seeds. 260-acre block (one unit) of S 84 oats. Average yield 25 cwt. grain per acre. Elevation 1100-1400 ft. Previously infested with dense bracken 4 ft. to 4 ft. 6 in. high. (Photo Abery, Builth. Courtesy Radnor. W.A.E.C.)

Fig. 16.—Breconshire (private enterprise)—S 100 white clover. Sown under barley; silage cut in May (4 tons "green" per acre); then put up for seed crop; yield 3 cwt. per acre. Mixture sown: S 100 at 4 lb. per acre, S 23 perennial ryegrass at 6 lb. per acre. (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

Fig. 17.—Breconshire—Cocksfoot S 143 in drills for seed. 1000 ft. 1st crop: approximately 5 cwt. clean seed per acre. (Photo Ian Trant. Courtesy Brecon. W.A.E.C.)

up with early management. Competition in seeds mixtures consisting of a blend of species and strains may depend on factors such as :—

(*a*) aerial shading especially from erect, quick-growing, short-lived species and/or strains, and

(*b*) a spreading habit of growth due to rhizome or stolon formation, and in the case of certain leafy strains of grasses, a high tillering habit.

Seedlings of certain grasses can persist in a dormant to semi-dormant state for long periods when conditions are unfavourable to their development through competition by other plants, and they can recover rapidly when such conditions are removed. Such latency in seedlings may be of supreme importance in agriculture. Furthermore, the effect of low temperature on germination is well marked—the action of low temperature in depressing the germination of *Festuca pratensis*, *Phleum pratense* and *Poa trivialis* to a greater extent than *Lolium italicum* is considered an important factor in interspecific competition (Chippindale, 1932).

There is considerable loss during over-wintering from the seeding to the first harvest year, but this is lower in some species than in others, while in some, more particularly among the fescues, the number of plants in the first harvest year is greater than in the seeding year. This phenomenon is, no doubt, largely due to a marked delay in germination (Aberystwyth, 1927). In laboratory germination tests, normal seeds of the grasses generally used in mixtures for Welsh conditions do not show dormancy. The evidence obtained at the Welsh Plant Breeding Station indicates that there is great variation in percentage establishment between various species and strains of herbage plants. There is also great variation in the establishment of the same species between field and field, and between season and season, depending on a variety of factors. (Additional references on this subject are Aberystwyth, 1928*a* and *b*, 1939*a*; Davis, 1938; Edwards, 1943; Price, 1939; Thomas, 1934.)

Depth of Sowing; Methods of Covering

As a rule, the Welsh farmer broadcasts herbage seeds on a rolled surface, either by hand or a hand-operated machine; after sowing, the seeds are lightly harrowed and rolled. Variations exist, however, as between district and district. Generally a good " take " is obtained, while the evidence indicates that both peg and chain harrows are equally effective for covering the seeds on most soil types—they do not bury the seeds too deeply; in any case there are sufficient seeds covered to a suitable depth to produce good results from a normal seed rate in mixtures.

Experiments conducted in 1920 (Williams, 1922) under controlled conditions (bed and pot cultures) and under field conditions where the seeds were sown under barley emphasize the desirability of proper covering to ensure good results. Better " takes " were obtained when the surface was slightly rough, since the roughness assists the seedlings to become attached to the soil-particles of from $\frac{1}{2}$ to $\frac{3}{4}$ inch in size. While surface sowings of red clover may not succeed because the radicle fails to penetrate the soil, white clover may become established well, provided there is sufficient moisture after sowing. Perennial ryegrass establishes better than cocksfoot and clover if buried

deeply ; seeds which are buried too deep may not attempt to germinate ; if they do germinate, the food in the caryopsis is exhausted before the seedlings reach the surface. Only a very small percentage of red and white clover seeds will become established well in normal seasons when they are buried to a depth of 1 inch. Hay strains of perennial ryegrass will establish when covered to a depth of from $\frac{1}{8}$ to 1 inch, but in a normal year $\frac{1}{2}$ to 1 inch is safer ; cocksfoot does better from a more shallow covering ($\frac{3}{8}$ to $\frac{1}{2}$ inch). Both perennial ryegrass and cocksfoot establish poorly when covered to a depth of 2 inches.

Optimum depth of sowing, however, is dependent on several factors, such as soil moisture, weather conditions, and size and type of seed. Although broadcasting has proved a successful method from normal seed rates for Welsh conditions generally, it is probable that on light soils, and especially on sandy soils and for sowings made in late May and early June, the drill would be superior as a method of sowing herbage seeds in most seasons even in the west of Britain. From general evidence the need for a close sowing drill is apparent.

The Use of Nurse Crops

The general method of sowing herbage seeds in Wales is under a cereal nurse crop (oats or barley) in spring (late March, April to early May). It is not the usual custom to sow in spring under winter corn. The practice of sowing without a cereal nurse crop and of sowing the seeds in June, July and even August with a light seeding of rape and Italian ryegrass, or with Italian ryegrass alone as a nurse crop, has increased appreciably during recent years, especially on the uplands and where fields are ploughed up from grass and reseeded " direct " on the prepared surface of the upturned turf.

The majority of farmers sow the herbage seeds on a rolled surface after the cereal, either on the same day or very soon afterwards. They will then lightly harrow and roll. A few farmers make a practice of sowing after the cereal (oats) has brairded. On good lowland soil where oats may be sown early in March, the sowing of grasses and clovers on the braird is successful and may sometimes be advantageous to the clovers which are sensitive to weather conditions and late frosts. On poor soils the necessary cultivations to prepare the seed-bed after the oats have brairded may have a damaging effect on the cereal. Early ripening spring wheats sown in early April make successful nurse crops. Winter wheat as a " nurse " for spring sowings of herbage seeds can be very successful, but the degree of success will depend on the cleanliness of the land and on the density of the stand of wheat. The necessary surface cultivations to prepare the seed-bed must, however, be thorough. The fear of disturbing the wheat plant through the use of harrows has led to failures of " take " of herbage seeds. If well-grown, autumn-sown wheat should be grazed in spring before the surface cultivations are carried out and the grass and clover seeds sown. When the surface soil is loose and there is a danger of the harrows tearing out too many wheat plants, it would be advisable to begin the preparation of the seed-bed by rolling with a heavy Cambridge roller.

Cereal nurse crops

The large number of trials conducted by the Welsh Plant Breeding Station over a number of years on a variety of soil conditions and under various

systems of management indicate that for Welsh conditions better results are obtained in the absence of a cereal cover crop harvested for grain. If there is a good crop of cereals, the effect of such a " nurse " is to retard the development of the " nursed " seedlings after a certain stage of growth has been reached. On the other hand, if a seeds mixture containing excessive amounts of Italian and/or perennial ryegrass is sown without a cereal cover crop the ryegrasses may do more harm than a cereal " nurse " crop, unless properly managed by controlled grazing (Aberystwyth, 1927). A heavy badly laid cereal crop, especially in wet seasons, may have a very damaging effect on seedlings of grasses and clovers ; where there are failures of " take," weed competition may be excessive if the land is not clean. Species slow to establish will thus suffer far more than quick-growing species and, if a severe winter follows, heavy seedling casualties will mean failure. The red clovers, in particular, need to be well established by the autumn, if they are to survive the rigours of winter, especially on the uplands. It is important to use an early ripening variety of cereal and thus give time for the developing seedlings after harvest to form strong plants before the winter.

Cereals when sown for silage make excellent nurse crops. When harvested early as hay they obviate to a considerable degree the danger of a lodging corn crop. In wet seasons, however, if there is rain after the cereals are cut they are very difficult to dry thoroughly and the hay becomes mouldy.

Cereal nurse crops for grazing

The small amount of evidence available at least indicates that some varieties of spring-sown cereals used for grazing make successful nurse crops for grass and clover seedlings. Haidd garw (= Scottish bere barley), Ceirch Llwyd Cwta (S.171 of the Welsh Plant Breeding Station) and Ceirch Llwyd (*Avena strigosa*) have all given good results on upland soils. As grazing plants, of course, they are not allowed to become advanced in growth and therefore they assist establishment through early consolidation instead of retarding the growth of herbage seedlings. Although they are high-tillering varieties they do not form too dense a canopy. " Haidd garw " grows very quickly. Cereal rye when sown in early autumn and grazed periodically in the following spring and summer also helps the establishment of grasses and clovers undersown in spring, even on exposed upland soils at 1200 feet above sea-level (Aberystwyth, 1936). The cereal is ready for grazing when the herbage seeds are sown and hoof cultivation from stock is thus assured from the outset. The chief drawback to the use of cereals in this manner is the price of seed. Probably, however, a relatively light seed rate would serve the purpose ; on exposed upland soils, autumn-sown rye is more sure of providing early keep than Italian ryegrass.

Rape and Italian ryegrass as " nurse " crops

As a " nurse " for developing seedlings, rape should be sown at a rate of not more than 2 lb. per acre, and should be grazed on an intermittent (" on " and " off ") basis while still in a young stage of growth. Rape managed in this manner makes a useful " nurse." If it is allowed to grow into a full crop before grazing starts, it has a damaging effect on the seedlings.

Italian ryegrass (at 6 to 10 lb. per acre) is generally included in mixtures with rape as a " nurse " ; sometimes it is used without rape. Italian ryegrass again must be kept well in hand and grazing must start as soon as there is sufficient keep available. The treading by stock entailed in this method of establishing pastures is an important factor—a dense sward is produced quickly, especially when leafy pasture strains are included in the seeds mixture. Furthermore, the early grazing and consolidation assist the young seedlings to become firmly rooted and make them better able to compete with weeds.

Time of Sowing

A complete answer as to the best time of sowing cannot be given—intensity of autumn and early spring grazing, sowing with or without a cereal nurse crop and other factors are very important, but the following points based on extensive studies over a period of years are also significant :—

(1) Date of sowing has a profound influence on establishment and on yields in the first harvest year. Species are affected differentially.

(2) The species that can in most seasons give moderate results from sowings made in September-October include only a few grasses which are able to make the most rapid growth as seedlings and young plants ; in Wales these species are perennial and Italian ryegrass.

(3) The clovers show a marked fall in establishment even when sown early in August. From the point of view of yields in the first harvest year August is on the late side even for the more rapidly growing species.

(4) Droughts accompanied by high temperatures are unfavourable to establishment.

(5) Relatively low temperatures (44° F. and below) when followed shortly after by higher temperatures will be harmful only to a few species ; if accompanied by excessive rainfall, establishment is lowered especially if the quality of the seed is poor ; therefore, although March is a dry month it is usually risky to sow before the end of the month. In a dry year, sowings are made as early as possible in April while the temperatures may be still low and the soil not dried out, while in a wet year the higher temperatures of May would favour seeds sown in that month. Early sowings give a prolonged opportunity to the young plants to establish themselves before the stagnant conditions of early winter set in (Aberystwyth, 1927).

In practice the farmer normally sows under a cereal cover crop and he has to take risks ; usually he sows his grass and clover seeds according to the weather conditions at the time he sows the cereal. As climatic conditions vary from season to season and from month to month, no specific date can be suggested ; generally speaking, April is the best month, although success can be achieved from sowings made in July or early August in most seasons, even on the uplands. The period from mid-May to mid-June is risky even under Welsh conditions, especially on thin soils. Long hot days with consequent rapid drying are more prevalent in most seasons at this period of the year.

Rate of Sowing

The usual rate of seeding for long duration leys varies roughly from 25 to 35 lb. per acre. Percentage early establishment naturally varies from field to field and from season to season, depending on several factors. First-class results in simple mixtures (leafy strains of perennial ryegrass and wild white clover) have been obtained from a total seed rate of 20 lb. per acre, while on clean soils in good heart in the drier areas there is evidence that under a nurse crop of oats productive pastures can be obtained from total seedings as low as 9 to 10 lb. per acre. From certain fields laid down for seed production of S.100 white clover a heavy silage crop has been harvested in May of the first harvest year and a seed yield of from 2 to 3 cwt. per acre obtained later; (mixtures of 6 lb. S.23 perennial ryegrass and 3 to 4 lb. S.100). (See Fig. 16.)

The evidence mainly relates to areas in mid-Wales with a rainfall of from 30 to 35 inches per annum, although similar results are reported from certain English areas. Evidence from the higher rainfall areas of the west on well-farmed land, both when sowings are made under corn or without a cover crop, also shows that a mixture of 10 lb. per acre of S.37 cocksfoot (for seed) and 5 lb. per acre early red clover can produce good swards quickly on light loamy soil after a previous heavy crop of rape and turnips has been grazed on the field. It is highly probable that where fertility is high and where the land is clean, first-class swards can be established from lighter seed rates per acre than is the general practice if reliance is placed on high-tillering leafy strains of grasses. Further investigations on this aspect of sward formation are now in progress.

The ability of a species or strain to tiller has, of course, a vital bearing on the plant stand under grazing management. The disadvantage of heavy seedling casualties in the winter of the seeding year may be offset, to a considerable degree, through the rapid production of an abundance of tillers in the first harvest year. An adequate seed rate of low tillering short-lived strains of suitable species may, however, be needed to provide grazing in the autumn and winter of the seeding year and the spring of the first harvest year. Such growth, of course, must be managed with a view to assisting the leafy strains to tiller and gain ground. On dry sandy soils in particular, and on thin soils generally, a relatively light seed rate may even be an advantage since soil moisture is one of the main limiting factors to success, particularly where the rainfall is somewhat low.

Having regard to all the factors that make for success in sward formation from sown seed, the power of a plant to gain ground through tillering or other vegetative means may probably be far more important, within certain limits, than early establishment in the formation of long-duration leys, while the capacity to tiller abundantly is linked up with grazing management, the strains of herbage plants used, and the maintenance of soil fertility.

Land Reclamation

Lowlands

Whereas a large acreage of derelict lowland fields has been brought into cultivation and rotation farming since 1939, a large number of fields have been

ploughed and reseeded direct to long duration leys either with or without a corn crop.

Somewhat wet rushy fields.—On many fields without elaborate drainage, rushes can be disposed of by periodic cutting and grazing and cleaning of ditches. Subsequently, if ploughed and reseeded, good pastures can be produced, with the plough furrows acting as temporary drains. Good results can be obtained under such conditions when the ploughing is carried out in January to February, or when ploughing, cultivating and seed sowing are carried out as one continuous operation. At the Welsh Plant Breeding Station an experiment on these lines dealt successfully with rushy turf containing a very high population of buried viable seeds of buttercup. The preliminary preparation of the tilth and harrowing killed a lot of buttercup seedlings. Sowing was carried out as late as mid-May, after which buttercup seedlings and sown seedlings were in competition with each other. By systematic "on" and "off" grazing, started 5·5 weeks after sowing, a very good sward was produced. Where buttercups, Yorkshire fog and *Agrostis* spp. make an immediate return, grazing accompanied by the mowing machine will help to keep them in check. On wet land which is difficult to plough properly, difficult to consolidate and difficult to graze because of the danger of poaching, the mowing machine, where it can be used, is an extremely valuable implement. Rushes often increase after ploughing and cultivation but the mowing machine can cope with them much more easily than when they are in a tough condition, as is usually the case before ploughing. Most arable weeds also can be disposed of through the use of the mowing machine and they should not be allowed to develop into a smothering crop and thus kill off young seedlings. Both rushes and thistles can be reduced slowly by "on" and "off" grazing accompanied by the mowing machine. The periods of rest between successive grazings should be reasonably long in order to allow the grass an opportunity to compete with the thistles, and the mowing machine should be used after each grazing.

Some farmers on somewhat wet fields have succeeded in establishing good pastures by ploughing and reseeding under corn—they maintain a rotation of corn-grass incorporating a four to five-year ley. An interesting experiment on lowland reclamation has been conducted on damp somewhat heavy land in Cardiganshire on a farm basis with the intention of establishing a small dairy farm. Several of the fields were covered with rushes, gorse, alder, willow and birch and there were acres of thicket through which it was literally impossible to pass (Figs. 4 and 5). The object has been to rely largely on intensive grassland farming and during the reclamation period (1937-41) there has been a marked advance in production. Although the work, on such completely neglected and starved land, has been costly, the data show how quickly production can be increased by ploughing and reseeding. Each of six fields near the homestead, ploughed, cultivated and reseeded, and managed on a rotational grazing basis, has been provided with a drinking trough. Another field (4·5 acres) of rushy poor grassland on heavy soil has been converted into a timothy meadow fescue ley for silage making. The field was ploughed in May 1940 by a Juno track plough and caterpillar tractor, disc harrowed twice and given 1 ton burnt lime and 5 cwt. basic slag per acre. In June it received 1 cwt. per acre sulphate of ammonia and was cut twice

later for silage—1st August and 1st September. Later in the year the field was grazed and closed in November in preparation for silage again in 1941.

The remainder of the farm becomes arable with short and medium duration leys. Out of a total area of 103 acres, 86 acres can be cultivated and may be termed second-class agricultural land. The increase in the physical volume of production as shown by milk sales between 1939-40 and 1940-41 is highly significant. In the preliminary report of the work dealing with land reclamation on the farm (Aberystwyth U.C.W., 1941) details of costings and output are given.

An example has been given of reclamation work from dereliction of the worst type. There are hundreds of acres throughout the country on fields near the homestead on dairy farms which for various reasons are not convenient for rotation farming, but they can be improved tremendously and quickly by direct reseeding after ploughing and cultivating. Milk output on such farms can be increased considerably.

Derelict upland fields and "open hill" grazings

Considered on a broad basis the chief types of unenclosed rough grazings in Wales are, as follows :—

(1) *Fescue-Agrostis pastures.*—These grazings are healthy but their production as a ration throughout the season is low ; they also tend to "brown off" or "burn" early in winter and they are late to start growth in spring. In sheltered pockets well supplied with moisture they are dominated mainly by *Agrostis* species with a sprinkling of wild white clover. Generally, *Festuca ovina* is the dominant species.

(2) *Molinia generally with Nardus.*—These grazings are associated usually with somewhat wet peaty conditions. As grazing units they have a very short season, while *Nardus* is very unpalatable. *Molinia* "tussocks" and foggage are neglected by stock, but after burning they are relished for a short period during the summer.

(3) *Bracken* is usually found on dry sheltered slopes ; when well grown it is found as a rule on good soil relative to upland conditions generally.

(4) *Heather* is often dominant on thin dry exposed areas.

Effect of lime and fertilizers ; no seed sowing and no cultivation

Data collected in connexion with the work of the Welsh Plant Breeding Station and the Cahn Hill Improvement Scheme over a period of years (Aberystwyth, 1930 ; Davies and Jones, 1932 ; Milton, 1940) have shown that surface applications of fertilizers and/or lime increase the yield of herbage, while they bring about botanical changes on unimproved, more or less, natural upland grazings on a variety of soil types in Wales. The increased yields due to incremental dressings of nitrogen in conjunction with a basal dressing of phosphate have been considerable. Further changes have resulted where lime is also applied. Generally potash fertilizers have not had a noticeable effect. These results indicate that low productivity is at least in part due to a paucity of plant food in the soil, in an available form. It has, however, been found that production will still be relatively low despite heavy applications of fertilizers unless more productive grasses and wild white clover

are introduced. Furthermore, the native herbage has naturally a short active growing season and it is late to start growth in the spring, an important factor to the hill sheep farmer.

A large amount of evidence from upland fields farmed on a rotation basis has shown that high tillering leafy strains of such species of grasses as cocksfoot and perennial ryegrass are more persistent and more productive over a period of years than the ordinary strains of commerce (Thomas, 1940*a*). The introduction of such plants with wild white clover on the open hill would improve these grazings.

Where relatively heavy periodic dressings of lime and phosphate are applied to some natural upland swards, wild white clover and some of the better grasses, such as rough stalked meadow grass, cocksfoot and ryegrass, may ultimately become established well, with an appreciable increase in the seasonal yield of herbage, under a rotational system of grazing. No seeds or plants of these grasses or wild white clover were present at the commencement of some of the trials under discussion, as shown by buried weed seed investigations and pasture analyses. The seeds were unintentionally carried to these plots on the clothing and boots of workers or by some other means. They established even on manured "hay and aftermath" plots to a small extent, and from these stock were excluded. The data show that lime was mainly responsible. These species did not voluntarily establish successfully, especially wild white clover, where superphosphate, kainit and nitrogen were applied in the absence of lime (Milton, 1940), nor, of course, on the unmanured areas.

To summarize certain chemical evidence in connexion with upland areas in mid-Wales, it may be said that the application of manures alone or manures accompanied by a mild form of cultivation increases the yield of herbage, which contains a slightly higher percentage of nitrogen, phosphoric acid and lime. But the produce, though superior in this respect to the untreated portions, is at best poor. It is only by thorough cultivation, liming, manuring and the introduction of lowland grasses that their produce becomes in any way comparable in nitrogen and mineral content to that found on the lowlands. Where cocksfoot, perennial ryegrass, dogstail and wild white clover can be established, animals grazing such areas on these uplands should not suffer from lack of phosphoric acid, lime or nitrogenous constituents (Fagan and Davies, 1937).

Establishing sown seeds on matted turf

No mechanical cultivation.—Even when heavy dressings of lime and phosphate are accompanied by severe grazing, wild white clover from sowings will not usually make any substantial contribution to the herbage for two, three or more years, especially on dry soils (Aberystwyth, 1936). As the wild white clover gains ground, the "mat" disintegrates, making conditions more suitable for the establishment of grasses. Until the "mat" is disposed of, germinating grass seedlings are unable to root in the soil and they die. The wild white clover as such makes a valuable pioneer plant, since the breaking down of the mat is an essential preliminary to the successful establishment and development of the better grasses. The evidence indicates that the sowing of the grasses should be delayed until wild white clover is well established;

reasonably heavy stocking, however, must be maintained if success is to be achieved. Both *Molinia* and *Festuca ovina* disappear fairly quickly after a dressing of lime and phosphate, if accompanied by more intensive grazing, especially where there is already a little wild white clover. Where *Festuca ovina* is associated with *Agrostis* species the latter increases at the expense of the fescue. As a method of grassland improvement, seed sowing in the absence of cultivation, even with generous dressings of fertilizers and lime, can be recommended only when other methods cannot be applied.

*Reseeding " direct " after ploughing and cultivating or after drastic surface cultivations only.**—Initial establishment differs materially on areas that have been ploughed in comparison with areas drastically harrowed, that is, harrowed enough to produce an earthy tilth. Often on somewhat steep slopes rolling is rendered difficult, and reliance must be placed entirely on consolidation by stock through grazing. Ploughed areas may, therefore, be initially unconsolidated while the harrowed surface is from the outset partially consolidated. Evidence is available where sheep have had access to the sown areas from the outset ; in other cases sheep have been kept off the sown areas for 6 to 8 weeks after sowing. Generally the grasses have established much better after ploughing than on a harrowed surface. On the other hand, wild white clover during the first year or so has been more successful on the harrowed surface. It is not known why this should occur, although lack of consolidation on the ploughed surface may be one factor. An inverted turf, previously perhaps never ploughed, may be devoid of the necessary active biological conditions for the successful establishment of clover in the early stages of sward formation. This is a problem which is now receiving further attention, as the same type of phenomenon occurs on old lowland pastures when ploughed and reseeded " direct." It would appear to be a more common feature on the wetter, colder soils and on peaty soils than on free working stony loams where aeration at plough depth may be somewhat better. Provided there is sufficient lime and/or phosphate in the soil, white clover will eventually establish successfully on the ploughed areas under systematic grazing management (Aberystwyth, 1936 ; Aberystwyth, 1940 ; Aberystwyth, 1941*a*).

Evidence is available to show that the clover nodule organism may be deficient on certain types of hill land in Wales. When these soils have been " inoculated " with transported soil from areas containing a high percentage of wild white clover, the establishment, vigour and nodulation of seedlings from sown seed of wild white clover have been assisted. Lime has assisted establishment without inoculation, but to a lesser degree. In the absence of phosphate, in the form of basic slag, lime would appear to be essential for nodulation, even with " inoculated " seed (Poulter, 1933). Inoculation by prepared " cultures " of the nodule organism also gave promising results. Different strains of the nodule organism differed in their ability to induce nodulation (Poulter, 1934).

Upland areas ploughed up on a large scale before and since the outbreak of the Second World War have given a great increase in stock-carrying capacity despite a paucity of clover in the early stages—areas with a carrying

* See Figs. 6 to 10.

capacity of less than a sheep per acre on an all-the-year-round basis have been intensively stocked with sheep and cattle. Perhaps the dearth of clover in the seeding and first harvest years when there is normally a flush of leafy herbage may not be entirely a disadvantage, bearing in mind the class of stock normally used, namely, store cattle and sheep. The management, however, should aim at safeguarding the appropriate subsequent development of the clover. Both perennial and Italian ryegrasses have established quickly on a variety of soil types after ploughing and they have contributed abundant luscious keep in 6 to 8 weeks after sowing.

In the trials under review Martin cultivators, tined harrows, disc harrows and rotary cultivators have been compared with the plough. By surface cultivations on old grass and despite drastic surface tearing there will always remain a certain amount of the living roots of native herbage to compete with the sown grasses, which will not establish a strong root system quickly unless there is a real depth of tilth. Where herbage is very rough and very matted, drastic surface harrowing may be necessary even after burning (where this is possible) and, therefore, to be really effective the procedure is expensive. Judged on this basis, there would seem to be no advantage from harrowing in comparison with burning slowly against the wind, followed by ploughing and subsequent sowing of a cheap mixture with the intention of ploughing again in 2 or 3 years when the remains of the " mat " have decayed to some extent. Probably the desired improvement is more rapid and economical by this latter method.

Eradication of bracken.—Even if bracken is cut twice a year (about early June and early August) for 3 or 4 years as a means of eradication, the associated herbage is still poor ; wherever possible, therefore, bracken land should be ploughed and cultivated, limed, manured and ultimately reseeded. This method is more effective and cheaper in the long run.

Although good results can be obtained on deep soils by ploughing at other times of the year, experimental evidence shows that it is more satisfactory to plough land dominated by bracken in July to early August. A heavy type of digger plough is suitable for the work. The ploughing should be deep and the furrow laid as flat as possible so as to bury all growth (Griffith, 1940). Subsequent treatment will depend on a variety of factors.

Pioneer crops

It has already been shown that poor old pastures can be greatly and rapidly improved by reseeding direct to a long-duration mixture on the prepared surface of the upturned sod. It is presumed that the basic principles in connexion with the formation of pastures from sown seed are more or less the same wherever it is possible for such sowings to succeed. Conditions must be created for the successful establishment of species and strains which will produce better herbage and more productive units. The use of pioneer crops in various ways on matted turf will help to create suitable conditions for the successful establishment of sown grasses and clovers (Aberystwyth, 1940 ; Aberystwyth, 1941*a* ; Griffith and Hutton, 1936).

Rape, hardy green turnips and mustard make excellent pioneer crops. The crucifers are generally sown from June to early August, but sowings can

be made in April or May. Their main purpose is to provide autumn and early winter feed for sheep and to build up fertility for further cropping. On inaccessible fields they often take the place of the root crop. On poor situations sowings should not be delayed after July ; whereas on the lowlands, rape (5 lb. per acre) may be suitable alone, on the uplands a mixture of rape (3 to 4 lb. per acre) and turnips (2 lb. per acre) should be sown. Turnips (4 to 5 lb. per acre) should completely replace rape on exposed upland fields of low fertility. On less exposed situations and in order to extend the grazing to the following spring, Italian ryegrass at 10 to 15 lb. per acre may with advantage be sown with the crucifers. Some farmers add a little mustard to the rape and turnips, claiming that it is beneficial to the health of stock.

The following rotations have given excellent results on suitable areas in land reclamation work on thin upland soils after calcium, phosphorus and nitrogen deficiencies have been adjusted.

1. 1st year. Plough, etc., sow a short-duration mixture with rape and Italian ryegrass.
   3rd or 4th year. Plough, etc., and reseed using Italian ryegrass as "nurse." Sow a long-duration mixture. Use a proportion of leafy pasture strains of grasses and wild white clover. Graze and do not take a hay crop. (A)
2. 1st year. Plough, etc., sow rape and turnips, or turnips alone. (B)
   2nd year. Disc ; sow rape and turnips and Italian ryegrass.
   3rd year. Plough ; sow a short-duration mixture under rape.
   5th to 6th year. As (A) above.
3. 1st year. As (B) above.
   2nd year. Disc ; sow a short-duration ley under rape.
   4th to 5th year. As (A) above.

On derelict upland fields, the following rotations have also been used :—

1. 1st year. Rape and turnips.
   2nd year. Cereal and seeds.*
2. 1st year. Cereal.
   2nd year. Rape and seeds.
**3. 1st year. Rape and turnips.
   2nd year. Cereal.
   3rd year. Roots.
   4th year. Cereal and seeds.*
**4. 1st year. Cereal.
   2nd year. Roots or rape and turnips.
   3rd year. Cereal and seeds.*
**5. 1st year. Turnips.
   2nd year. Cereal.
   3rd year. Cereal.
   4th year. Rape and seeds. (Fig. 11).

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* Usually oats and a long-duration ley.
** Common normal rotations on upland farms.

Since the outbreak of the Second World War and as part of the home food production campaign a very considerable acreage of upland rough grazings has been brought into cultivation. Large blocks dominated by tall bracken on relatively deep soil have been ploughed in the summer and sown with rape and turnips and reploughed in the following spring for potatoes. Excellent yields of virus-free potatoes have been harvested, especially in the lower rainfall areas. The soil requirements in fertilizers and lime must be provided. Potatoes do not thrive on acid soils of this type unless lime is applied. Oats and seeds after potatoes have produced good results. (See Figs. 12 to 15.)

Analysing the available evidence as a whole, the use of pioneer crops on suitable areas is definitely to be recommended because the dung and urine of the grazing animal, in particular, increase the general fertility of the land and help to break down the old turf, and in this way make conditions for the establishment of sown seed of superior grasses and clovers more certain. The precise procedure to adopt in connexion with such reclamation is dependent on several factors, including cost, rainfall, steepness of slopes and the immediate needs of the farmer.

The following mixtures and practices have also been used successfully for building up fertility :—

1. Mixture of crucifers to include kale, mustard, rape and turnips on inaccessible lowland fields to replace the root crop. They provide useful food for sheep and bullocks, while the dung and urine from the stock are invaluable for subsequent crops. Sometimes reasonably accessible fields are treated in this manner and grazed by dairy cows ; even rape alone has been used for this purpose.

2. (*a*) Sheep have been folded in July and August on a mixture of rape (4 lb. per acre) and early red clover (6 lb. per acre) sown in April.

(*b*) Winter oats (including S.147 of the Welsh Plant Breeding Station) and vetches sown in early autumn have been grazed by sheep folded on the crop from April to June on some less exposed upland fields in mid-Wales, especially on red sandstone. Cereal rye and vetches have been used with success for the same purpose ; the rye must be kept well in hand in spring. If there is a danger of the crop getting out of hand a part is harvested as silage.

Lime and Manures

Successful pastures cannot be produced unless the soil contains an adequate supply of plant food in an available form.

Lime

The present intensive ploughing-up campaign has emphasized the acute need of lime on Welsh soils. Despite a considerable revival of a common old practice, there are still thousands of acres of agricultural land in an extremely acid condition. Many crop failures have been due to lack of lime, while red clover is very sensitive to deficiency. In the higher rainfall areas of the west lime may be washed out of the soil quickly. Lime has a marked beneficial effect both on the establishment and maintenance of grassland. On acid soils

complete success cannot be achieved from phosphate dressings unless calcium requirements are first provided. Calcium carbonate (ground limestone) is as effective as calcium oxide (lump lime or ground lime) when equal amounts of calcium are applied. The advantages of ground limestone on wet soils are important in wet climates where proper slaking and uniform distribution may be difficult. On rotation land, lime is usually applied after the root crop before the cereal and seeds are sown. It is, however, often applied at other stages in the rotation.

Lime alone acts slowly, but generous dressings can maintain a fair sward from sown seed for many years. In conjunction with nitrogen, young seedlings establish reasonably well after lime and they will persist for some years if heavy dressings of the latter are applied. Evidence of this nature is available from " direct " reseeding without a cover crop on upland soils where stock have had access to plots from the date of sowing; production, however, continues to be low on these phosphate-deficient areas unless phosphate is also applied.

Phosphates

Basig slag *alone*, generously applied (10 cwt. per acre), gives quicker and better results than lime *alone* (2 tons ground burnt lime per acre) even on somewhat acid soils, but a light dressing of lime in addition to the phosphate is very advantageous. Both superphosphate and slag give a great fillip to initial establishment of grass seedlings; light dressings will assist materially (Aberystwyth, 1936). Normally 4 to 6 cwt. of a high-grade basic slag or 3 or 4 cwt. per acre of superphosphate is applied on rotation grassland; when reseeding direct more generous dressings are generally advisable, especially on upland deficient soils. The quick-acting property of superphosphate is useful when herbage seeds are sown late in summer, on light soils containing lime. For lasting results generous dressings of phosphate are needed where there is serious deficiency; if this cannot be done because of limited supplies, a second dressing should be applied early to prevent deterioration. For continued high production in long-duration leys containing a proportion of leafy pasture strains of grasses and clovers, an adequate supply of lime and phosphate in the soil must be maintained. A biologically active turf free from " mat " may thus be assured for many years under suitable management. The more slow acting ground mineral phosphate (North African phosphate) also gives good results, especially on heavy land in wet areas.

Potash

Normally most Welsh soils are well supplied with potash. The increase in the area of cultivated land and the removal of straw crops since 1939 has depleted soil reserves to some extent, particularly as the supply of farmyard manure is insufficient properly to meet the demands made on it. Many arable fields, therefore, when reseeded have shown a need for a dressing of potash.

Inorganic nitrogenous fertilizers

These are valuable for pioneer crops and to assist seedlings to establish successfully; they also help to give extra growth at times when it is especially

needed. They are very useful as a top-dressing for autumn keep after the corn harvest, while a spring dressing will, in most seasons, give valuable keep on sheltered fields a fortnight or so earlier than the normal time. Nitrogen fertilizers, judiciously applied, can increase grassland production considerably in the higher rainfall areas, but a balance of other plant food in an available form must be maintained in the soil. After a wet winter light soils lying fallow may be very deficient in available nitrogen.

Repeated cutting of *Molinia caerulea* weakens the plant considerably and quickly. In trials on upland peaty soils in a very acid condition dominated by this species periodic cutting in conjunction with dressings of sulphate of ammonia brought about a change-over in dominance to *Deschampsia flexuosa* and *Festuca ovina*. Where nitro-chalk was used instead of sulphate of ammonia colonization was mainly by *Agrostis* species. The cuts were made monthly (May to October) and the fertilizer applied after each cut at the rate of approximately 1 cwt. per acre. A basal dressing of superphosphate was applied annually. It is possible that the lime present in nitro-chalk in this case was partly responsible for the different results from the two nitrogenous fertilizers tested (Jones, T. E., 1933). Similar results were obtained with sheep, where the grazing management was controlled, except that even after sulphate of ammonia, *Molinia* was replaced mainly by *Agrostis* species (Milton, 1940). Further investigations with generous applications of lime are in progress. Seedlings do not respond to nitrogen in the absence of phosphate and/or lime (Aberystwyth, 1936)—this has been clearly shown in hill trials.

Farmyard manure

A light dressing of dung on thin soils after the corn has been removed helps seedlings to overwinter successfully. Dung is still regarded as the basis of sound farming practice, but its place in the rotation varies from district to district and from farm to farm. Generally the root crop is generously dunged, especially on fields near the homestead, while many farmers still manage to give a periodic dressing to their hay meadows. Artificials in addition to dung are usually given to the root crop. Limited supplies of dung and phosphates to meet the heavy demands of wartime farming have modified standard practices to an appreciable extent.

The manurial treatment at sowing time of grass and clover seeds sown under a cereal nurse crop after roots depends on the manures applied during the rotation ; generally reliance is placed on the residue after the roots because of the danger of lodging in the cereal.

Seeds Mixtures

During the last 20 to 25 years plant breeders, especially at the Welsh Plant Breeding Station, Aberystwyth, have devoted detailed attention to the question of " strain " in herbage plants (Aberystwyth, 1928*b*, 1939*a*, 1941*b* ; Stapledon, 1939). Strains of grasses and clovers have been developed which are fundamentally important in relation to the formation of long-duration pastures from sown seed. The bred strains, although later to start growth in the spring than ordinary commercial strains, are more productive of total

herbage over a period of years both as hay and pasture ; they are more leafy, they persist better under hard grazing conditions, and they tiller abundantly. Ordinary commercial strains of perennial ryegrass, cocksfoot and timothy are short-lived, but because they are earlier to start growth in the spring than leafy pasture strains they are useful for a year or two ; they then die out quickly, especially under grazing management. All mixtures for 3 years or longer should contain a proportion of leafy strains of grasses and in some cases, on poor soils, even 2-year grazing leys would benefit from a few pounds in the mixtures. The detailed evidence on the effect of competition between species and strains in mixtures also has an important bearing on the types of mixtures now recommended. When compounding mixtures, it is essential to include species and/or strains that blend ; species and/or strains which fail to establish successfully in competition under a defined system of management should not be included. In the past several species which were recommended in mixtures made practically no contribution to the herbage.

Each species and/or strain must serve a definite purpose and each must be included at an adequate seed rate per acre, which rate differs markedly for different species and conditions. For good results the grazing must be properly controlled. The successful establishment of mixtures and the formation of long-duration leys, therefore, are determined among other things by the mixture, by the conditions set up by the grazing animal, by soil fertility and by climatic conditions.

It is impossible in a short note to give lists of mixtures to suit all types of soil and climatic conditions under different systems of management. The following notes are therefore given as a rough guide in compiling mixtures for various purposes and conditions. The " S " numbers denote strains developed at the Welsh Plant Breeding Station.

Simple ryegrass-clover mixtures

On good soils first-class long-duration pastures can be produced from a mixture of strains of perennial ryegrass with S.184 and/or S.100 white clover. The hay strains of perennial ryegrass (S.24 and/or commercial) at 10 to 14 lb. per acre are valuable for the first few years for early keep, while the pasture strains (S.23 and/or S.101) at 8 to 12 lb. per acre will hold the ground successfully in the later years and for many years. Such swards cannot be produced when reliance is placed on hay strains alone as deterioration is rapid even under good management.

Ryegrass-cocksfoot-clover mixtures

Mixtures consisting of perennial ryegrass (12 to 18 lb. per acre) as the dominant species, with cocksfoot (4 to 8 lb. per acre) as subdominant are recommended on loamy soils over a wide range of conditions in Wales. Whereas in a variety of conditions cocksfoot S.26 is reasonably persistent even when grazed hard and often, on exposed upland conditions in particular cocksfoot S.143 (extreme pasture strain) gives better results. The total seed rate of cocksfoot (all strains) under these poor conditions may be as high as 7 to 8 lb. per acre. The blend of strains and the seed rate to be used will depend on the soil conditions and on the severity of grazing. Where the grazing is lenient,

cocksfoot S.37 (hay strain) will persist reasonably well as a grazing plant and in this respect it is considerably better than ordinary commercial strains. Ordinarily when sown under corn, in mixtures containing a heavier seed rate of perennial ryegrass, cocksfoot does not contribute well until late in the first harvest year or even until the second year. Where it is desired to produce a cocksfoot-dominant pasture quickly for special purposes, 12 to 16 lb. per acre (all strains) may be used—the seed rate of the associated strains of perennial ryegrass will then be correspondingly lower (6 to 10 lb. all strains).

It is a common practice in certain parts of the higher rainfall areas of Wales to overgraze in winter and spring and to undergraze in summer. On moderately thin soils under such management, when pasture strains of perennial ryegrass at a low seed rate per acre are sown in mixtures with pasture strains of cocksfoot at heavier seed rates, the tendency is for the ryegrass to be suppressed for some years after the first harvest year and the sward becomes mainly cocksfoot. Ultimately, however, the perennial ryegrass with wild white clover will dominate the sward. The perennial ryegrass (high tillering strains) gains ground rapidly through tillering as the cocksfoot, which for some years has been aggressive and which has borne the brunt of the grazing, weakens. Furthermore, the dung and urine provided by stock will have created conditions more suitable for the ryegrass to compete successfully. Evidence of this nature is available from seed rates of pasture strains of perennial ryegrass as low as 5 lb. per acre in mixtures with 20 lb. per acre of pasture strains of cocksfoot. Commercial cocksfoot soon dies out under this system of management and it is a poor competitor even in the third year. The data indicate that leafy strains of perennial ryegrass can survive a long period of unfavourable conditions and thrive when suitable conditions prevail. This is an important factor when seeds are scarce and emphasizes the necessity for including even small amounts (even 4 lb. per acre) of pasture strains of perennial ryegrass in mixtures (Thomas, 1940*a*, 1940*b*).

When normal seed rates are used and where the system of management provides regular rest periods between successive grazings, pasture strains of cocksfoot will persist and blend well with pasture strains of perennial ryegrass and wild white clover on such soils for many years and high production can be maintained.

Ryegrass-timothy-clover mixtures

As a species, timothy is best adapted to heavy loams, clay soils and peaty soils ; the bred strains will, however, contribute appreciably under moderately hard grazing conditions on a variety of soil types. Perennial ryegrass (12 to 18 lb. per acre all strains) and timothy (4 to 6 lb. per acre all strains) may thus combine well to make first-class pastures. Timothy S.50 forms a dense sward and is typically a prostrate pasture strain. Timothy S.48 is useful for hay and grazing while timothy S.51 produces valuable leafy hay and is more persistent than ordinary strains for grazing. Where a timothy-dominant pasture is required, the seed rate should be increased to 12 to 16 lb. per acre (all strains) and the perennial ryegrass strains reduced (4 to 6 lb. per acre).

Ryegrass-cocksfoot-timothy-clover mixtures

Good pastures may also be produced under suitable management from a blend of strains of the three species mentioned, namely, perennial ryegrass (10 to 12 lb. per acre), cocksfoot (4 to 6 lb. per acre) and timothy (4 to 6 lb. per acre). Proportionate contribution to the herbage will depend on management since timothy is sensitive to competition from ryegrass and cocksfoot.

Meadow fescue-timothy-clover mixtures

Meadow fescue (10 to 12 lb.), more particularly the bred strain S.53, is valuable for special purposes with timothy strains (10 lb.), but it is not a good competitor in mixtures containing perennial ryegrass, cocksfoot and the red clovers, especially in the early years of sward formation. With a blend of strains of timothy it produces a heavy late hay crop on moist loams and peaty soils in reasonably good heart.

Basal seeding in all mixtures

It is recommended that all the types of mixtures described should contain S.184 wild white clover (or commercial genuine wild white clover) and/or S.100 white clover at a combined seed rate of 1 to 2 lb. per acre. On good soils S.100 alone does well for several years ; on poor soils S.184 is safer while on a variety of soils a blend of S.184 and S.100 should be suitable.

Italian ryegrass (2 to 10 lb. per acre) should also be included in almost all mixtures. It must be managed as a pasture plant and not as a hay plant. The amount to include per acre depends on the intensity of grazing during the first autumn and spring after sowing. If such grazing is lenient then 2 lb. are ample ; if more severe 4 to 5 lb. can be used. When reseeding without a cereal cover crop, 8 to 10 lb. per acre can be used with safety, but it must be kept well in hand.

Red clover is not essential in grazing mixtures, but 1 to 2 lb. per acre may be beneficial ; the deep roots help to aerate the soil. Where hay is to be harvested for 1 or 2 years after sowing, 3 to 4 lb. per acre should be included in the mixture. On soils well supplied with lime and phosphate, 3 lb. should be ample on the lowlands. For good conditions a mixture of early and late strains may be used ; on poor soils and especially on the uplands, reliance should be placed mainly on the late strains, especially the extra late strains S.123 or Montgomery red clover.

Crested dogstail (1 lb. per acre) is recommended in mixtures on exposed thin upland soils.

In all long-duration mixtures it is recommended that a mixture of strains of the species should be used in order to provide as long a grazing season as possible. The amount of each strain to include in the mixture will depend on the duration of the ley, on grazing management, and on soil and climatic conditions. The minimum poundage of pasture strains for 4-year leys and longer should be at least one-third of the total seed rate of the species. For the first year or two, early feed will be provided by the erect short-lived strains. Although in subsequent years spring keep will not be quite so early, the pasture strains will respond well to a dressing of nitrogen in spring and thus provide reasonably early feed especially on sheltered fields. They provide more autumn

keep than the hay strains even in the first year under most systems of management.

Except in limestone soils the ordinary strains of lucerne have given very mixed results in trials even when inoculated. On some of the deeper soils it is possible that improved strains may do well provided the soil is adequately supplied with lime. Further investigations are in progress. Sainfoin is included in mixtures and grown for seed in parts of Glamorganshire.

Mixtures for one and two-year leys

The total acreage in Wales in short-duration leys is relatively small even in wartime. It is the common practice to seed down for 3 to 4 years or longer. For 1 and 2-year leys a seed rate of 20 to 26 lb. per acre is usual. Generally the mixtures recommended consist of up to 20 lb. of the ryegrasses (Italian and hay strains of perennial) and up to 6 lb. of red clover. For 1-year leys reliance is placed on the early red clovers only ; their partial replacement by 2 to 3 lb. per acre of the late flowering strains is recommended for 2-year leys. Usually hay is taken in the first and/or second year. Where no hay is taken, 2 lb. red clover per acre should be enough. In mixtures for grazing only, 1 lb. per acre of S.100 white clover may be added with advantage. The proportion of perennial ryegrass to Italian ryegrass should be higher in 2-year leys than in 1-year leys.

Hay strains of cocksfoot and timothy, each at 3 to 4 lb. per acre, are often included in 2-year mixtures. Cocksfoot especially is useful in the second year both for hay and for grazing in the aftermath, particularly on thin soils.

For one-year leys on peaty soils a mixture of hay strains of timothy (12 to 16 lb. per acre) and alsike (5 to 6 lb. per acre) does quite well. Trefoil (*Medicago lupulina*) is not recommended for mixtures on Welsh soils generally, except on limestone formations. Sown at the same time as the cereal as a catch crop (8 to 10 lb. per acre), however, it would appear to furnish useful autumn feed on red sandstone soils well supplied with lime and phosphate.

Strains bred at the Welsh Plant Breeding Station

Perennial ryegrass

S.23. Late flowering ; spreading growth ; high tillering, dense and leafy ; spring growth less rapid than ordinary types ; summer growth abundant under suitable conditions and continues well into autumn and winter if relatively mild ; very persistent under proper grazing management ; responds well to nitrogen if adequate lime in soil ; blends well with S.184, S.100 and wild white clover ; fairly persistent even under poor conditions, at least where rainfall is not very low.

S.24. Slightly earlier and more abundant in spring growth than Irish and Ayrshire in flower somewhat later ; bulky hay, aftermath better than Irish and Ayrshire ; summer growth very leafy ; more persistent than ordinary strains, less persistent than S.23 and S.101.

S.101. In flower slightly earlier than S.23 and is less spreading but leaf blades longer and broader ; leafy late hay ; very persistent on good soils, not so suitable for hard grazing as S.23 on relatively poor conditions ; responds well to nitrogen.

Cocksfoot

S.37. Relatively erect; slightly later in flowering than Danish; mainly for hay; grazes well if not too severe on good soils; less persistent than S.26 and S.143, especially on uplands.

S.143. Produces dense cushions; very valuable and persistent under poor conditions; tillers abundantly, leaves broad and palatable. (Fig. 17.)

S.26. Plants large and leafy; a pasture type but gives good leafy hay; persistent on poor soils and at high elevations; later flowering, more leafy and more highly tillering than Danish types.

Timothy

S.48. Late flowering; winter green and high tillering; resistant to rust; yields well as hay and very persistent as a grazing plant on medium to heavy soils.

S.50. Extreme pasture type; flowering stems very short; roots at nodes and thus propagated vegetatively.

S.51. Leafage comes high up the stem; highly resistant to rust; mainly a hay type; high tillering; persistent under moderate grazing; wintergreen.

Red clover

S.123. Late flowering; slow in spring but dense; branching more profuse than in ordinary red clovers; heavy hay yields in first and second year and good crops often obtained in third year; also makes a good pasture plant.

S.151. Earlier than S.123; slightly shorter but more leafy and stems more numerous and more persistent than ordinary broad red clover; heavy yield of hay in first harvest year and good aftermath; surviving plants quite numerous in second harvest year.

White clover

S.100. Forms dense leafy sward; surface runners which readily root at nodes; good for silage; persistent under good conditions; long growing season for a white clover; earlier than wild white clover and continues growing later in autumn. (Fig. 16.)

S.184. More uniform than wild white clover; runners more slender than S.100; growth not tall but dense; as persisent as wild white; used under similar conditions and for similar purposes as wild white clover.

Fuller particulars of these and other strains of the Welsh Plant Breeding Station are given by Jenkin (1943).

Early Management

In order to maintain pastures in first-class condition for a period of years it is essential to choose the mixtures carefully, and also properly to control the management of the grazing animal. The grazing animal is the master factor in deciding the balance of the constituents contributing to the sward. It has been demonstrated that a uniform pasture containing leafy strains of grasses and wild white clover when subjected to different schemes of grazing management will change materially in botanical composition very quickly (Aberystwyth Imp. Bur., 1933). The aim must therefore be to keep the persistent leafy strains in a vigorous and healthy condition every year while the field is in pasture. Early and late growth each has its special value; management must aim at making full use of such seasonal growth.

Long-duration mixtures, sown under a cereal cover crop

Competition starts early: immediately the cereal crop is removed, therefore, management must aim at providing suitable conditions for the successful

establishment of the sown species. After the removal of the cereal crop the developing pasture should be rolled when the soil is dry to assist the seedlings to root firmly. Italian ryegrass, which is usually included in mixtures, grows quickly and is pre-eminent as a pasture plant of short duration. If managed mainly for hay, it has a smothering effect on the more slow-growing but longer-lived species; it must, therefore, be kept well in hand. Grazing on an intermittent ("on" and "off") basis should start as soon as Italian ryegrass provides sufficient keep. The grazing should be properly controlled and should not be so severe as to damage young seedlings of other species. Young cattle are well suited for this purpose although both cattle and sheep have a beneficial effect in assisting consolidation. A heavy head of stock should be turned in to graze down the available herbage quickly.

Spring keep

Grazing in the first winter should be lenient and the field, especially if reasonably sheltered, should be managed with the object of providing spring keep. For this purpose a dressing of nitrogen (sulphate of ammonia or nitro-chalk) should be applied in late February to early March at about 1 cwt. per acre. On suitable fields grazing can thus start a fortnight or so earlier in spring, in most seasons. The pasture should not be excessively grazed at any period. On wet soils care should be taken not to "poach" the land.

Subsequent grazing management

Well-regulated intermittent grazing should be the rule throughout the season and in every year. Stemmy growth should be mown over. Closeness of mowing will be governed by the presence of stones, but the machine should be adjusted to cut as low as possible in order to promote tillering.

Where growth becomes completely out of hand a light hay crop or silage should be harvested. The rapid formation of a dense sward is important, especially on poor soils. Grazing in the first year will help both wild white clover and the high-tillering strains of grasses to spread and fill in the base of the sward. In dry situations and particularly in the lower rainfall areas of the eastern border it may be beneficial to allow the plants to develop a strong root system during the early summer of the first year; in such cases a silage cut in May or a light hay crop in June after a short rest period may be advantageous. The condition of the fences and the absence of an efficient water supply are limiting factors to the adoption of a definite scheme of rotational grazing on all fields; but it is a system which should be extended wherever possible as it provides the opportunity, by varying the management as required, to develop and maintain the desired type of sward. Regular rest periods between successive grazings increase production and a useful balance between wild white clover and leafy sown grasses is maintained. Ll. I. Jones (1933, Aberystwyth, 1939*b*) has shown in experiments with sheep that monthly periods of rest between successive grazings give more production in the form of live weight than fortnightly or 4-day periods of rest, while unsown species are kept out more effectively. There is also higher production in the following year. The actual period of rest between grazings will depend on the rate of

growth of the herbage and on the prevalence of *Agrostis* which needs keeping well in hand, especially in July to August.

The same fields should not be grazed heavily early in spring every year ; the species and/or strains with a long grazing season suffer most by this method of management. In practice, and especially on upland farms, it is often difficult to avoid excessive grazing in spring. For grazing in the autumn, winter and early spring, Italian ryegrass sown with the first cereal crop where two cereal crops are grown in succession may be invaluable where heavy demands are made on young leys. It will help to offset the difficulties connected with the excessive grazing of the young leys in the spring, except on very exposed upland conditions. Where there is strong growth the cereal may be cut high ; on the other hand, if the cereal stand is thin, Italian ryegrass will help to keep down weeds.

Management for hay and aftermath

Fields should be closed for hay in late March to early April after first grazing down Italian ryegrass. The crop should be cut in June and bulk should be sacrificed for quality. Hay cut late is stemmy and low in nutritive value, and furthermore the growth of aftermath is poorer. Fields " put-up " to hay usually benefit from a dressing of nitrogen in April, using sulphate of ammonia or nitro-chalk at 1 cwt. per acre. The aftermath should be grazed on an intermittent basis and it should not be allowed to grow too long before stock are turned in to graze (Stapledon and Davies, 1926).

Pastures on upland soils are often closed for hay in the first, second and perhaps the third year after excessive and prolonged spring grazing. It is a practice not to be recommended but circumstances sometimes make it necessary. Usually a generous seeding of Italian ryegrass is included in the mixtures. Where hay must be taken in the second or third year, spring grazing should be controlled ; the field should be closed reasonably early and the hay cut early. Hay cut late is generally of very poor quality partly on account of poor harvesting weather. The necessity for including leafy pasture strains is extremely important for these conditions.

Direct reseeding under rape and/or Italian ryegrass

In connexion with direct reseeding it is extremely important to bury the old turf completely ; to prepare a suitable surface tilth well consolidated below ; to cover the seeds properly and to roll well after sowing, if possible. Grazing should commence as soon as there is sufficient herbage available, and this should be continued on a well-regulated intermittent basis, as far as possible during the whole life of the ley. Hay should not be taken during the year of sowing. If hay must be taken in the following year it should be cut early.

Conclusion

Although Wales is eminently suited to grassland husbandry, it is only during the last 20 to 25 years that detailed research work has been carried out in connexion with the formation and management of pastures produced from sown seed. The technical evidence which has been discussed in this paper is

based primarily on the work of the Welsh Plant Breeding Station and the Cahn Hill Improvement Scheme both on their own land and on farms in various parts of the Principality. The work of pioneer farmers and, since the outbreak of the Second World War, some of the results achieved through the work of County War Agricultural Committees have also been studied. In the aggregate, therefore, the evidence is linked up with a variety of soil and climatic conditions and systems of farming. The tremendous acreages of permanent grass and rough grazings which have been brought into cultivation since 1939 have provided ample opportunities for studying reasons for failures and successes. A considerable acreage of old grassland which has been ploughed, cultivated and cropped has failed to produce the desired yields through phosphate and/or lime deficiency. The need for sensible rotations with adequate periods of rest as leys is a feature strongly revealed in crop yields on farms throughout the country. Despite scarcity of labour and of fertilizers, the intensive ploughing-up campaign has led to a very marked increase in home food production. A well-thought-out cropping plan, on a broad and flexible basis, to suit the requirements of individual farms for the maintenance of the land in good heart will still increase the average production per acre materially.

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For the past century it has been customary for the Scottish farmer to put some land down to grass each year as part of his ordinary rotation of crops. Latterly, however, interest has become widespread in ploughing up areas outside the usual rotation and seeding them down direct to grass. This method has been gaining in popularity and spreading so fast that there is considerable danger of the reseeded area increasing faster than the rate of increase in stock necessary to maintain it in proper condition afterwards.

In the main, such reseeding is done on marginal land which had gone out of cultivation during the past 50 years, but it also includes considerable areas of rough heather ground which had never been previously ploughed.

Weather Conditions

Scotland has a climate which is very suitable for vegetative growth of grass over a long continuous period from the beginning of April to the end of October. The annual rainfall varies from just under 30 inches on the eastern coastal fringe to over 80 inches in the mountainous districts of the western half of the country, but what is of most importance for grass production is that a summer drought is very exceptional.

Ploughing and Cultivations

On the rotation ground, there is little difficulty in obtaining a suitable seed-bed, the ground being ploughed in the ordinary way during the winter months as early as possible after the root crop has been cleared away.

Where direct reseeding is to be carried out on a tough old matted turf the problem is very different. The ploughing has to safeguard two things, namely, first the complete burial of the surface weeds so that none of the old plants are able to send up shoots between the furrow slices, and second the re-establishment of an efficient contact between these furrow sections and the earth below, so that any lack of rainfall for periods up to a month or 6 weeks will not allow that upper layer to dry out. The covering of the surface weeds and particularly of the tussock clumps is done most effectively by cutting wide furrows from 16 up to 26 inches wide with a depth up to 10 inches where possible. This width obviates the difficulty of any furrows standing on their edges or vacant spaces remaining within the ploughed section. The fibrous old turf, however, is inclined to form an objectionable cushion between the ploughed and the unploughed layers of soil, acting as a barrier to free movement of moisture from one layer to the other. It is advisable to rip up the old surface by cultivation before the ploughing is done as this helps to break down the mat much quicker.

Where time is not an essential factor, the cost of this surface cultivation can be saved and yet the same object achieved by ploughing during the previous summer or early autumn, thus allowing a sufficiently long interval for the mat to rot down on its own, in which state it makes an ideal link between the two layers of soil. The problem of obtaining a suitable surface tilth is also solved by this early ploughing; on difficult ground it is more economic to

spread out the various operations than to force a tilth in an expensive manner by recourse to extra cultivation. Over-cultivation is apt to bring divots to the surface and these will grow again.

Manuring

Soil analyses have shown that most of the areas in Scotland are deficient both in lime and phosphates. Much of the land is distinctly sour; the first step is therefore to supply lime, usually as ground limestone at the rate of 2 to 3 tons per acre. Shell sand as found on particular sea coasts is often used as an alternative. This sand contains a high proportion of carbonate of lime, but as the shells in the natural state are rather coarse and slow-acting a higher initial rate of application is needed.

For phosphate, anything from 5 to 10 cwt. per acre of basic slag is usually applied or an equivalent containing a fair proportion of phosphate in a readily available form. Although the potash content of the soil is generally low, there is usually sufficient to allow the grasses and clovers to become established.

With the exception of the " haughs," which are low-lying stretches subject occasionally to river flooding and usually covered with dense clumps of tussock grass (*Aira caespitosa*), the areas selected for ploughing and reseeding direct are generally low in available nitrogen. For the initial start of the new seedlings, therefore, a light dressing of a quick-acting nitrogenous manure is applied. The subsequent accumulation of supplies of nitrogen in the soil is always left to the clover plant, wild white clover being an essential constituent of the seeds mixture.

Having once applied the essential plant foods to the ground, it is then necessary to ensure that they are not removed through the agency of the grazing animal. Animals feeding on herbage take in a considerable amount of nitrogen, phosphate and potash, of which only a small proportion is retained in the body. By far the greater part of these constituents appears in the excrement, and it is vital in the interests of the maintenance of fertility for them to be returned to the soil from whence they came, so that they may be utilized again by the superior herbage plants for which they were originally supplied. Where only a portion of the land has been ploughed, reseeded and manured, fencing becomes essential to control the animals and prevent them from spreading the manurial ingredients over larger adjoining areas, which in practice would generally be populated by inferior plants less able to give returns commensurate from such manurial ingredients. Under Scottish conditions it is probable that a considerable portion of the manurial ingredients traverses the complete cycle, from the soil into the plant and through the animal back again into the soil at least three times per grazing season.

Time of Sowing and Initial Establishment

In the ordinary rotation area, the seeds are sown in spring under a cereal nurse crop following a root crop which is regarded as the cleaning crop of the rotation. There is little difficulty in obtaining successful establishment with this method as the seeds are sown on clean ground which is in good heart and has a fine tilth. Under such conditions any failures that do occur are

usually due to the fact that the cereal nurse crop is too heavy or has become lodged. During the war years, however, poor establishment of clover has become more frequent due to a deficiency of phosphate.

In pre-war years the only manurial dressings given to the "sown-out" crop were phosphatic, and these were fairly heavy. Now there is a tendency to replace that phosphate with a compound manure generally called "grain and grass manure" and containing nitrogen as well as phosphate. Not only does this compound provide less phosphate to the ground, but the nitrogen in it encourages a larger grain crop; more phosphate is thus removed from the soil, and a totally inadequate supply of phosphate remains for the grass and clover seedlings.

On areas which are being reclaimed the cereal nurse crop may be dispensed with altogether or replaced by a crop such as rape, which is used for fattening lambs in the autumn. The inclusion of rape largely controls the date of sowing of the grass and clover seeds under these circumstances, all the seeds being mixed together and sown in June or early July. This method usually results in good establishment of the herbage seeds, but occasionally, if there are not enough animals to graze down the crop quickly, the rape becomes too strong and checks the young seedlings, particularly the clovers. Again, should the grazing of the rape be delayed too long at the commencement, there is a risk that it may become somewhat fibrous, in which case the lambs will prefer to graze the grass and clover seedlings.

Where no nurse crop is employed the seeds can be sown at any time from mid-March to the end of August, the risk of drying out being practically non-existent if the ploughing has been done correctly and sufficiently early. A delaying of this operation until late July or August is a disadvantage, as a considerable portion of that summer's growth is lost, while in addition the seedlings will lack vigour for the autumn and winter months. On the other hand, sowings made on exposed situations before the ground has acquired the warmth of May may lead to a slower and more uneven germination. This means that, instead of bringing in the grazing stock 6 weeks from the date of sowing, as is customary with sowings in May and June, the initial stocking has to be delayed, and undesirable volunteer weed species are given a better opportunity to become established.

Initial Grazing

Cattle are preferable to sheep for the initial grazing, as cattle always remove the more erect tillers and thus prevent the formation of seedstalks. In this way the cattle encourage the continuous development of more new tillers at the base, whereas sheep are inclined to leave the older shoots and nibble at the young basal shoots instead.

In any case it is rather a dangerous practice to put in sheep for a few weeks first and then follow up later with cattle. By that time many plants will have tough erect shoots which are taken by the cattle and the whole plant is pulled up; if the cattle are put in earlier they will take only the leaves, which being succulent and tender will break off before the roots give way.

Method of using Rotation Grass

The system generally adopted with rotation grass is to take a hay crop during the first year and to graze it for the next 2 years, when it is ploughed again for another oat crop. The practice of haying during the first year results in a somewhat open sole during the second year and often in a rather weedy sward in the third year, the unpalatable Yorkshire fog (*Holcus lanatus*) locally known as " pluff grass " being all too prevalent. Recently, in spite of a prejudice against first-year grass for grazing, many farmers have changed their practice. By utilizing the grass during the first year for grazing instead of hay, a full sole of herbage is developed immediately together with the desirable spread of the white clover ; the grass and clover both serve very efficiently as a check on volunteer weeds. This practice was becoming fairly common before the war, when the production of first-quality beef was the main purpose of the leys. With a little adjustment in the rate of stocking to prevent the grass from running into stem in June, a fattening pasture can be developed right from the beginning.

Method of using Reseeded Pastures

A fundamental principle in grassland farming is that the plants are grown for the sake of the grazing stock. Working on this basis, the prevailing idea is that once the seedlings of the grasses and clovers have become established, the needs of the grazing animal should take precedence *at all times* over the needs of the plants themselves. This is particularly the case where sheep are concerned, the animals being allowed to run over the ground throughout the year.

During the winter and early spring, green succulent fodder is very scarce, and so the more productive any plant happens to be at that critical time the more heavily is it grazed and thus weakened. In fact, the more useful the plant the more it itself suffers for giving good service, and the weaker it will be later during the summer months when it has to compete with less useful plants (those starting late). Under such management, or rather lack of proper management, the pasture usually serves the flock very well for the first year, moderately well during the second year, and then falls off rather quickly by the third and fourth year, when the superior and early-starting plants will have disappeared from the sward.

That is the history of a great many areas that have been temporarily improved by reseeding, and the farmer is faced with an expenditure of £12 per acre to repeat the process if the standard of usefulness is to be maintained for another 4 years.

Such deterioration of pastures is looked upon as inevitable on all land with the exception of exceedingly small acreages in the famous fattening districts. Everywhere else it has been accepted without question that the best grasses will disappear in a few years after sowing. The method adopted in laying down a pasture has therefore been to combine in the seeds mixture a range of plants each of which would in turn dominate the sward, just when its immediate superior would drop out. For instance, Italian ryegrass would be included for its value in the first winter and spring as being the earliest

and most winter-productive grass. Perennial ryegrass would be included as its immediate successor, being the next best for production during the following winter and early spring. A year later cocksfoot would be expected to provide spring keep although it would be rather brown in winter. A still later grass, usually referred to as "a bottom grass," such as crested dogstail, would be included to take over the ground as the cocksfoot waned. All these were included with the idea of delaying as long as possible the time when bent (*Agrostis*), a grass late to start in spring and early to turn grey in autumn, would become dominant.

The whole system was based on the idea that there was nothing that could be done to prolong the life of the more useful species; the farmer's maxim was therefore to take as much as possible out of each individual plant as long as it was present.

New Outlook on Pasture Management

In view of the knowledge gained during the past 20 years concerning the different methods of stocking pastures and their effect in encouraging and prolonging the life of any particular species, the time is surely ripe for a new outlook on our methods of managing pastures.

Instead of allowing the best species to drop out after a very brief service, steps should be taken so to arrange the utilization of the sward that the lives of these good species may be trebled, or better still made to continue indefinitely even on second and third-rate land. The economics of grassland improvement can be entirely altered in this way. An outlay of £12 per acre on direct reseeding may be an economic proposition if that improvement is maintained at a fairly high standard for 12 years, whereas the same outlay per acre would be quite uneconomic if the improvement lasted for only 4 years.

Henceforth, therefore, the farmer should select the particular species he wishes, and then aim at providing the conditions suitable for that species to persist. This means studying the changes that are necessary in our methods of management to suit the particular grasses, instead of merely accepting the old system of management as unchangeable and in a lame way trying to adjust our seeds mixtures to agree with a deteriorating scale of usefulness.

That it is both possible and practicable to substitute this new method for the old has been shown in an experiment carried out in Inverness-shire on the farm of Mr Grant, Knockie. On high exposed land ploughed out of heather in 1938 and sown direct to grass in the spring of 1939, over a hundred hoggs * have been wintered each season on 30 acres of hill land of which only half could be reseeded. The remaining half was too difficult to plough and was allowed to remain as rough heather, although included within the fence. Counting the rough heather with the treated area, the reseeding made it possible to winter at home each season as many as six hoggs for each acre ploughed. Yet the sown species persist; the perennial ryegrass which is remarkably winter-green is still dominant, being as plentiful and vigorous in its sixth winter season as it was in its first year. This may seem all the more remarkable since it has been utilized for carrying the ewe hoggs from October to early April for the past five winters.

* In Scotland refers to male or female sheep 6 to 12 months old.

This performance has undoubtedly been due to the treatment given during the remainder of each year, namely :

From mid-April to mid-May—the first weeks of active growth at this elevation—no stock are allowed on the land, so that the early plants have an advantage before the late plants start, and also while they themselves are still in the leaf-producing stage—the building-up stage.

From mid-May to mid-August, twenty Highland cows and their calves are put in with the express purpose of keeping all the grass eaten well down. These cattle are looked upon as implements, although they are quite profitable in this respect, their calves doing exceedingly well.

During the third period—mid-August to end of September—all stock are removed so that the plants have an opportunity to prepare themselves for the winter.

The cattle in their grazing confer several benefits on the sward. In the first place they prevent any plants from wasting energy on seed production. Instead, energy is diverted to the production of new tillers resulting in a denser sole. In the second place, they obviate any selective grazing as they prevent all the tall plants alike from growing beyond the young succulent palatable stage. This hinders the development of less palatable species and facilitates the spread of the creeping white clover.

Then the droppings play a part : by consuming summer growth on the spot, the cattle through their droppings ensure a liberal supply of readily available plant food, which helps autumn growth very considerably.

The fact must not be overlooked that, in examples like Knockie, these Highland cows require some provision for long spells of hard weather during the winter. Mature cows can, however, deal with fibrous fodder fairly efficiently, and can utilize straw and second-class hay which are quite unsuitable for sheep, particularly young sheep. Hence, the wintering of this class of cattle is possible with the by-product fodders of lowland arable farms.

A significant point in connexion with this experiment is that the sheep obtain full benefit from the growth of the best plants during that period of the year when they need the grazing, *while the plants receive first consideration during the rest of the year*, the cattle being regarded mainly as implements. We have here the sward performing each year the function for which it was laid down and yet, judging from its present condition, there is no reason to expect that the good plants will disappear for at least another 6 years, if at all. On the other hand, had the stock been allowed to graze without any control, a custom all too frequent on this kind of land, the best plants—particularly the perennial ryegrass—would no doubt have disappeared in two seasons and their place taken by inferior grasses far less capable of producing winter and early spring growth.

Seeds Mixture

Under a system of controlled grazing, the simplicity of the mixture is of paramount importance, for basic to the system is the fact that at certain times of the year the good plants will be abused *to a certain extent* in the interests of the grazing animal, but at some other time these good plants will be protected and allowed to regain their normal vigour. It is very important that during

this recuperative stage the good plants do not have to suffer competition from inferior plants that might derive more benefit by protection at that period. This point influences the choice of species in the seeds mixture, for it is important to exclude any species that make management more difficult. For instance, in the Knockie experiment, the perennial ryegrass derived more benefit from the rest periods in spring and autumn when sown alone than when cocksfoot was sown as well. The still later-starting bent (*Agrostis*), on the other hand, did not benefit much from a rest period before mid-May, and therefore did not adversely affect the perennial ryegrass.

A further point is that where a plant rather low in the fertility-demanding scale, such as crested dogstail, is eventually to be the dominant grass in the sward, the inclusion of ryegrass or cocksfoot, either of which will be dominant at first, does not afford the optimal conditions for the full establishment of the dogstail. Plants still lower on the scale such as bent or the fine-leaved fescues may then have an opportunity to encroach when the ryegrass and cocksfoot are disappearing.

* * *

The problem of grassland improvement on second-rate land turns on the relative economics of two systems. Where no control is exercised over the grazing animal, the pastures are exploited on a short-term policy, the cost of renewing outrun pastures recurring every few years. The alternative is to aim at maximum production over an extended period by having some regard to the well-being of the sown plants as well as of the animals feeding on them—controlled grazing. Experience under dry conditions in the South-east of England has shown that plants which continue to form succulent shoots during drought periods (for example, cocksfoot) may be utilized at those critical times and yet persist for many years *provided* at other times there is proper control of the grazing in favour of these useful plants.

In the case of our arable plants, both cereals and roots, we realize that in order to secure a full crop, certain conditions or pre-treatments must be given. Such pre-treatments as planting or sowing at the proper time and guarding against injury are necessary in order that the individual plants may have an opportunity to develop properly. The same principle holds just as strongly in regard to our pasture plants, the herbage being the crop of our grasslands. The sward should therefore be treated each year in such a manner that it will subsequently be able to contribute its maximum effort at any desired period.

Further, it is the writer's opinion that when this principle is put into practice in dealing with the grasslands in various parts of the world, two major facts will emerge :

In the first place, many of the high-yielding species and strains which we now classify as short-lived plants are really capable of being quite persistent if they are properly managed from the very beginning.

Then on the strength of that, it will be possible to widen the range over which many of our present species can be grown and will be useful. In fact, at the present time we are asking the plant breeder to solve many problems which should be tackled along agronomic lines.

Importance and Distribution of Pasture

Pasture and range land in Canada involves an area of over 61 million acres. The importance of pasture is clearly indicated by the acreage devoted to it as compared with the acreage in grain and hay as shown in Table 1. These data are based on the records of the Eighth Census of Canada, 1941.

Table 1

Acreage of Pasture compared with Hay and Grain in Canada

	Total Area Occupied Farms	Grain	Cultivated Hay	Pasture			
				Improved	Natural	Total	Percentage Improved of Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	
Prince Edward Island	1,168,858	185,603	218,353	237,062	80,604	317,666	74·6
Nova Scotia	3,816,646	91,841	385,896	175,283	732,831	908,114	19·3
New Brunswick	3,964,109	236,204	556,176	292,887	364,491	657,378	44·5
Quebec	19,287,775	2,175,406	3,908,055	2,693,337	2,442,431	5,135,768	52·4
Ontario	22,364,316	4,718,227	3,682,377	3,228,070	3,966,354	7,194,424	44·9
Total Eastern Canada	50,601,704	7,407,281	8,750,857	6,626,639	7,586,711	14,213,350	46·6
Manitoba	16,891,322	5,720,844	406,549	454,799	4,821,661	5,276,460	8·6
Saskatchewan	59,960,927	19,147,115	430,537	782,926	19,783,222	20,566,148	3·8
Alberta	43,277,295	11,164,042	598,116	630,564	18,723,101	19,353,665	3·3
Total Prairie Provinces	120,129,544	36,032,001	1,435,202	1,868,289	43,327,984	45,196,273	4·1
British Columbia	4,033,570	197,949	258,463	171,619	1,828,365	1,999,984	8·6
Total in Canada	174,764,818	43,637,231	10,444,522	8,666,547	52,743,060	61,409,607	14·1

It may be seen that the total area in pasture in Canada constitutes 35 per cent of the total area of occupied agricultural land, whereas grain and hay represent only 25 and 6 per cent respectively. The percentage of improved pasture, as shown also in Table 1, varies considerably in different provinces. The acreage of improved pasture is extremely low in the Prairie Provinces of Manitoba, Saskatchewan and Alberta, due chiefly to a very extensive use of large areas of native grassland for pasture or range for cattle. The low percentage of improved pasture in Nova Scotia results from a fairly extensive use as pasture of rocky and partially wooded areas which are too rough to be cultivated.

According to the "Quarterly Bulletin of Agricultural Statistics" there was in Canada, in 1941, a total of 12,349,000 cattle and sheep distributed as shown in Table 2, p. 56.

In addition to this there were 2,881,000 horses in Canada in 1941. Although it is true that not all the horses are pastured, yet the fact remains that feed must be provided for them either as pasture or hay. From the foregoing data it is readily seen that the carrying capacity of Canadian pastures is low, there

being only a little over 15 million cattle, sheep and horses carried on over 61 million acres of pasture and over 10·5 million acres of cultivated hay. It has been found, however, that on some improved pasture it is possible to carry one or more animals on an acre of land throughout the grazing season. On

TABLE 2

Number of Grazing Animals by Provinces in Canada

Provinces	Milch Cattle	Other Cattle	Total Cattle	Sheep
Prince Edward Island	44,000	51,000	95,000	46,000
Nova Scotia	113,000	108,000	221,000	139,000
New Brunswick	112,000	97,000	209,000	109,000
Quebec	1,010,000	765,000	1,775,000	666,000
Ontario	1,204,000	1,367,000	2,571,000	802,000
Manitoba	322,000	434,000	756,000	233,000
Saskatchewan	532,000	818,000	1,350,000	488,000
Alberta	418,000	1,040,000	1,458,000	897,000
British Columbia	131,000	232,000	363,000	171,000
Total in Canada	3,886,000	4,912,000	8,798,000	3,551,000

the other hand, in some areas, particularly in the Prairie Provinces, it takes from 20 to 40 acres of range pasture to support one grazing animal per year. Therefore, the methods of pasture improvement to increase production and thereby increase the carrying capacity per acre are of national importance.

Climatic Conditions in Relation to Pasture

The type of pasture varies considerably in different localities, as affected by climatic conditions and the kind of farming which is followed. On the Pacific coast in the Province of British Columbia (see soil-climatic map, p. 57), the marine type of climate is characterized by moderate to heavy rainfall except where modified by the Rocky Mountains. There is much cloudy weather and fog and the temperature is mild throughout the year. In the valleys, and where favorable mountain climate prevails, pastures thrive very well.

East of the foothills of the Rocky Mountains in the Southern section of Alberta, Saskatchewan and a small section of Manitoba lies a relatively large area of land where the climate might be described as semi-arid. Here rainfall is light and uncertain, ranging from 10 to 20 inches annually, and strong desiccating winds are prevalent. In the south-western part of this area, some 35,000,000 acres of range land provide the bulk of the forage for 1,815,000 horses, 3,564,000 cattle and 1,618,000 sheep. The chief vegetation in the district is designated as short-grass prairie. This area has been noted for its many large ranches and is in close proximity to the wheat belt of the Canadian Prairies which lies to the north and east. Farther north in the three Prairie Provinces is the park belt where mixed farming is practised.

Eastward, in the provinces of Ontario and Quebec, the climate changes to a humid continental type with irregularity of weather conditions such as a

Fig. 18.—Beef cattle on Kentucky bluegrass permanent pasture in Eastern Canada.

Fig. 19.—Dairy cattle on alfalfa-grass pasture in Eastern Canada.

Fig. 20.—Beef cattle on range land—Prairie Provinces.

Fig. 21.—Sheep grazing on the short-grass plains of Southern Alberta.

SOIL-CLIMATIC MAP
OF
CANADA
BRITISH COLUMBIA
ROCKY MOUNTAINS
ALBERTA
SASKATCHEWAN
MANITOBA
HUDSON BAY
ONTARIO
QUEBEC
LABRADOR
NEWFOUNDLAND
NEW BRUNSWICK
P.E.I.
NOVA SCOTIA
SMITHERS
PRINCE GEORGE
BEAVERLODGE
FORT VERMILION
LACOMBE
SCOTT
ROSTHERN
MELFORT
WINDERMERE
AGASSIZ
SUMMERLAND
SAANICHTON
LETHBRIDGE
MANYBERRIES
SWIFT CURRENT
REGINA
INDIAN HEAD
BRANDON
MORDEN
KAPUSKASING
NORMANDIN
STE. ANNE DE LA POCATIERE
CAP ROUGE
L'ASSOMPTION
OTTAWA
FARNHAM
LENNOXVILLE
FREDERICTON
CHARLOTTETOWN
NAPPAN
KENTVILLE
DELHI
HARROW
SOIL ZONES
1—Brown Soil Zone
2—Dark Brown Soil Zone
3—Black Soil Zone
4—Grey Wooded Soil Zone
5—Pacific Coast Soil Zone
6—High Lime Soil Zone
7—Eastern Podsol Soil Zone
8—Precambrian Soil Zone
9—Grey Brown Podsolic Soil Zone
10—Tundra
CLIMATIC DATA
AT DOMINION EXPERIMENTAL STATIONS
Mean Annual Precipitation
Mean Annual Temperature

wide range in temperature from day to day and season to season and with intermittent rain and sunshine. The average annual precipitation ranges from 25 to 35 inches about equally distributed between summer rainfall and winter snowfall. This is the area of small grains and cultivated forage crops with considerable permanent pasture. Dairying and mixed farming are the general type of agriculture followed. There are approximately 12,000,000 acres of pasture in Ontario and Quebec. The production of grass is relatively high in the months of May and June, but in general the growth is seriously retarded by the hot, relatively dry weather of July and August. During this period supplementary feed in some form must be provided.

The three eastern provinces of New Brunswick, Nova Scotia and Prince Edward Island also fall within the area known as the humid continental type of climate, but there the conditions are modified by proximity to the Atlantic Ocean. Being located to the leeward of large land masses these provinces receive the combined continental influence of the land as well as the moderating effect of the sea. These conditions provide a more abundant rainfall with more even distribution. Changes in temperature are more gradual and less extensive. This combined with a longer growing season characterized by cool, cloudy and often foggy weather provides almost ideal conditions for the production of permanent pastures. Hay and grain can also be grown satisfactorily and the dairying industry is the chief source of wealth. In addition, potatoes, vegetables and fruit are produced extensively.

Meteorological Data on Dominion Experimental Farms

Fairly complete meteorological records have been taken over a considerable number of years on Dominion Experimental Farms and Stations throughout Canada. Since pastures are so greatly affected by climatic variations, precipitation and temperature records are presented in Tables 3 and 4 based on data from 31 stations located at representative points across Canada. These data will serve to supplement the more general observations already made regarding climatic conditions. The distribution of rainfall or the number of days on which rain was recorded during the 5 months of the growing season at the various stations is shown in Table 5. (See also soil-climatic map of Canada, p. 57.)

Soil Conditions

Soil conditions must also be recognized as an important factor affecting pasture production and these are very closely related to climate. (See soil-climatic map, p. 57.) The Pacific coast soils developed under mild winters and heavy rainfall are characterized by a low content of organic matter, by a yellowish-brown to reddish-brown surface soil and by relatively high acidity.

In the semi-arid climate of South-Eastern Alberta and Southern Saskatchewan the soil has developed under the short grass vegetation, and is known as brown soil. It is light to drab brown in color and on the average shallower and lower in organic matter and nitrogen than the other prairie soils. A lime layer generally occurs at a depth from 6 to 12 inches.

Immediately north and east of the brown soil area, under somewhat higher moisture conditions lie the dark brown soil areas of the Prairie Provinces.

TABLE 3—*Mean Monthly Precipitation (inches): Dominion Experimental Farms*

Station	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Years													
Charlottetown, P.E.I.	33	4·07	3·40	3·59	2·87	2·79	2·83	3·07	3·26	4·19	4·34	3·83	4·74	42·98
Kentville, N.S.	29	4·00	3·14	3·26	2·78	2·51	2·85	2·95	3·21	3·67	4·23	3·95	4·04	40·59
Nappan, N.S.	34	3·32	2·76	2·92	2·64	2·42	2·79	2·93	3·10	3·63	3·96	3·60	3·69	37·76
Fredericton, N.B.	29	3·50	2·59	3·14	3·21	2·66	3·33	3·10	3·55	3·49	3·75	3·05	3·14	38·51
Ste Anne de la Pocatiere, P.Q.	30	2·79	2·60	2·61	2·65	3·06	3·59	3·59	3·22	3·68	3·29	2·71	2·37	36·16
Cap Rouge, P.Q.	28	3·66	2·76	2·77	2·92	3·42	4·24	4·13	4·37	4·36	4·03	3·61	3·03	43·30
Normandin, P.Q.	6	2·07	2·10	2·29	1·78	2·17	3·27	4·06	3·93	3·60	2·53	2·35	2·93	33·08
Lennoxville, P.Q.	28	3·21	2·35	3·10	2·77	2·84	3·98	4·15	3·60	3·73	3·74	3·27	2·95	39·69
Farnham, P.Q.	22	3·02	2·16	3·01	3·36	2·89	3·47	3·71	3·35	3·93	3·33	3·40	2·87	38·50
L'Assomption, P.Q.	13	3·10	2·31	2·88	2·88	2·69	3·29	3·82	3·41	3·34	2·93	2·94	2·95	36·54
Ottawa, Ont.	53	2·98	2·40	2·65	2·32	2·74	3·39	3·67	3·00	2·94	2·68	2·63	2·84	34·24
Harrow, Ont.	25	2·03	1·99	2·26	2·58	2·12	2·81	2·13	2·20	2·56	1·87	1·83	2·01	26·39
Delhi, Ont.	8	3·26	3·32	2·72	3·19	2·72	2·79	3·34	2·22	3·35	2·78	2·95	2·83	35·47
Kapuskasing, Ont.	25	1·96	1·11	1·71	1·84	2·10	2·53	3·30	3·18	3·48	2·19	2·30	2·04	27·74
Morden, Man.	24	0·85	0·90	1·10	1·29	2·14	3·12	2·77	1·89	2·10	1·26	1·15	0·89	19·47
Brandon, Man.	47	0·89	0·67	0·96	1·17	1·95	3·13	2·81	2·50	1·92	1·03	0·86	0·79	18·68
Indian Head, Sask.	46	0·77	0·69	1·06	0·89	1·91	3·47	2·32	1·98	1·74	1·20	0·90	0·76	17·69
Swift Current, Sask.	57	0·67	0·58	0·71	0·80	1·79	2·97	2·17	1·78	1·21	0·75	0·50	0·60	14·53
Regina, Sask.	50	0·52	0·35	0·66	0·81	1·70	3·06	2·17	1·71	1·30	0·82	0·58	0·42	14·10
Rosthern, Sask.	29	0·60	0·47	0·82	0·86	1·36	2·54	2·53	1·71	1·52	0·91	0·68	0·69	14·69
Scott, Sask.	31	0·68	0·59	0·66	0·90	1·44	2·33	2·18	1·56	1·32	0·73	0·62	0·69	13·69
Melfort, Sask.	31	0·53	0·32	0·71	0·71	1·63	2·48	2·74	1·99	1·90	0·93	0·74	0·49	15·17
Lacombe, Alta.	35	0·62	0·63	0·75	1·15	1·96	3·38	2·78	2·37	1·56	0·82	0·70	0·63	17·35
Lethbridge, Alta.	41	0·63	0·67	0·87	1·14	2·35	2·77	1·74	1·55	1·72	0·90	0·75	0·67	15·76
Manyberries, Alta.	14	0·56	0·48	0·73	1·01	1·33	2·71	1·33	0·73	0·99	0·67	0·59	0·59	11·71
Beaverlodge, Alta.	27	1·32	0·89	1·21	0·82	1·50	2·05	2·32	1·85	1·79	1·21	1·35	1·25	17·55
Ft. Vermilion, Alta.	34	0·66	0·39	0·60	0·52	1·27	1·75	1·88	1·66	1·25	0·71	0·58	0·62	11·90
Windermere, B.C.	26	0·90	0·54	0·41	0·57	1·14	1·66	0·91	1·35	1·10	0·80	0·60	1·11	11·10
Summerland, B.C.	27	0·97	0·70	0·67	0·70	0·90	1·17	0·75	0·65	0·80	0·82	0·97	1·35	10·45
Agassiz, B.C.	48	7·67	5·72	5·41	4·23	4·24	3·84	1·93	2·17	4·21	6·56	8·04	8·26	62·26
Saanichton, B.C.	29	4·36	3·27	2·66	1·49	1·07	1·07	0·67	0·74	1·43	2·98	3·76	6·10	29·60

TABLE 4—*Mean Monthly Temperature (Deg. F.): Dominion Experimental Farms*

Station	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Years													
Charlottetown, P.E.I.	33	18·3	17·1	26·6	37·1	48·5	58·7	66·1	65·3	57·7	48·1	36·7	24·8	42·1
Kentville, N.S.	29	20·6	20·0	29·0	39·5	50·3	59·7	66·3	64·9	57·7	48·2	37·1	25·3	43·2
Nappan, N.S.	29	17·3	16·7	26·9	37·7	48·7	58·3	64·4	63·5	56·3	46·4	35·1	22·5	41·1
Fredericton, N.B.	29	12·3	14·4	26·3	39·2	51·0	60·5	66·2	64·3	56·5	45·8	33·0	19·1	40·7
Ste Anne de la Pocatiere, P.Q.	30	10·9	11·9	23·4	36·4	49·3	59·1	64·9	62·5	53·9	43·7	30·5	15·9	38·5
Cap Rouge, P.Q.	28	11·2	11·6	22·2	36·7	50·8	60·1	65·9	63·5	55·2	44·7	30·7	16·9	39·1
Normandin, P.Q.	6	−1·0	5·3	14·1	33·1	49·1	59·6	63·8	61·6	51·8	40·3	25·9	7·9	34·3
Lennoxville, P.Q.	28	12·6	13·2	24·7	39·8	51·7	61·3	66·3	64·0	56·2	44·9	32·5	18·0	40·4
Farnham, P.Q.	22	13·9	14·3	26·7	40·6	53·7	63·0	67·5	65·8	57·9	46·3	33·9	19·5	41·9
L'Assomption, P.Q.	13	11·6	11·8	23·5	40·3	54·5	63·9	68·4	66·2	57·8	45·7	32·3	15·9	41·0
Ottawa, Ont.	53	11·8	12·7	24·7	41·4	54·9	64·6	68·9	66·3	58·5	46·2	32·4	17·3	41·6
Harrow, Ont.	25	24·9	27·3	35·0	45·7	57·6	68·1	72·9	70·3	65·0	52·7	39·9	29·6	49·1
Delhi, Ont.	8	22·1	22·5	31·6	43·5	56·0	65·8	70·7	68·4	60·7	49·5	38·1	27·2	46·3
Kapuskasing, Ont.	25	−1·5	2·6	13·9	31·5	46·1	57·6	62·4	60·1	51·3	39·1	22·2	6·9	32·7
Morden, Man.	24	3·5	7·5	20·2	38·1	53·1	62·2	69·0	66·5	56·3	42·8	24·3	9·9	37·8
Brandon, Man.	44	−1·5	2·3	18·3	37·8	51·1	60·1	65·5	62·7	52·7	40·3	21·5	6·6	34·8
Indian Head, Sask.	36	0·3	5·3	18·9	37·1	50·3	59·6	65·2	62·2	52·1	39·3	22·3	8·1	35·1
Swift Current, Sask.	21	9·2	12·9	25·0	39·9	52·2	59·3	66·2	62·9	52·7	41·2	25·9	14·5	38·5
Regina, Sask.	50	−0·3	2·6	16·5	37·7	50·7	59·7	64·7	62·1	51·9	39·3	21·6	8·3	34·6
Rosthern, Sask.	29	−3·4	2·5	15·7	37·3	51·5	59·7	64·6	61·5	50·9	38·3	20·5	5·1	33·7
Scott, Sask.	31	−0·3	3·7	16·5	35·8	50·1	57·5	61·1	60·9	50·4	38·3	21·5	7·1	33·5
Melfort, Sask.	32	−2·7	3·0	15·9	36·1	49·7	58·1	63·1	59·6	49·6	37·3	19·5	4·7	32·8
Lacombe, Alta.	35	8·5	12·3	23·3	39·1	49·3	56·1	61·1	58·5	49·7	39·9	24·7	12·9	36·3
Lethbridge, Alta.	41	17·3	18·5	28·9	42·1	51·0	58·6	64·5	62·3	53·3	44·5	31·5	21·9	41·2
Manyberries, Alta.	14	12·7	12·8	26·9	41·7	53·3	60·4	69·0	65·9	54·9	43·1	27·3	18·1	40·5
Beaverlodge, Alta.	27	8·7	13·1	22·3	37·5	49·1	55·5	60·0	57·8	49·3	39·1	23·0	11·7	35·6
Ft. Vermilion, Alta.	34	−11·1	−4·2	9·5	31·3	47·9	55·9	60·8	57·5	46·2	32·9	10·5	−5·5	27·6
Windermere, B.C.	26	13·5	19·5	31·5	42·3	50·7	57·3	62·8	60·7	50·9	40·7	27·0	15·9	39·4
Summerland, B.C.	27	25·7	29·3	39·5	48·6	56·4	63·7	70·4	68·7	59·5	48·9	36·6	29·3	48·1
Agassiz, B.C.	48	35·1	38·2	43·8	49·9	55·7	59·9	64·4	64·1	58·2	51·1	42·4	37·7	50·0
Saanichton, B.C.	24	37·9	39·3	42·9	47·9	53·9	58·9	62·7	62·1	56·5	49·7	43·3	39·4	49·5

These are deeper and contain more organic matter and nitrogen than the brown prairie soils. The lime layer is usually found at depths of 10 to 16 inches.

Farther north is a band of park land with higher precipitation, tall grasses and the beginning of tree and shrub growth. The soils known as black soils

TABLE 5

Average Number of Days with Rain: Branch Farms and Stations (Growing Season)

Station	May	June	July	Aug.	Sept.
Charlottetown, P.E.I.	13·0	12·5	11·7	12·1	12·9
Nappan, N.S.	10·4	10·3	9·7	10·0	10·0
Kentville, N.S.	11·7	11·9	10·5	9·8	11·0
Fredericton, N.B.	11·7	12·0	11·6	10·5	10·8
Ste Anne de la Pocatiere, P.Q.	10·4	10·5	11·3	9·2	10·6
Lennoxville, P.Q.	11·3	12·2	12·4	10·2	10·7
L'Assomption, P.Q.	9·8	11·2	11·1	9·6	9·8
Normandin, P.Q.	10·5	13·8	13·5	14·5	15·3
Ottawa, Ont.	11·7	11·5	11·8	10·0	11·0
Harrow, Ont.	9·3	...*	7·4	7·4	7·7
Delhi, Ont.	9·5	9·5	8·8	7·4	9·0
Kapuskasing, Ont.	10·0	10·7	11·6	11·0	13·6
Morden, Man.	7·2	9·7	9·0	7·9	6·9
Brandon, Man.	8·1	10·7	9·9	8·7	7·3
Swift Current, Sask.	10·8	13·2	10·2	8·9	8·7
Rosthern, Sask.	7·2	10·8	9·3	8·0	5·7
Melfort, Sask.	8·2	11·4	10·0	9·1	8·0
Lacombe, Alta.	9·9	13·5	12·3	10·6	8·5
Lethbridge, Alta.	10·0	10·8	7·7	7·0	7·4
Manyberries, Alta.	9·2	12·4	8·4	6·1	7·1
Ft. Vermilion, Alta.	6·4	8·3	8·8	8·1	6·3
Summerland, B.C.	7·0	8·2	5·3	5·3	6·8
Agassiz, B.C.	14·0	13·2	7·2	7·5	10·7
Sidney, B.C.	9·5	7·6	4·2	5·1	7·6

* No record.

are dark brown to black in colour and rich in organic matter and nitrogen. The surface layer may vary from 4 inches to 2 feet in depth and the lime layer occurs between 15 and 36 inches below the surface.

Still farther north are the grey wooded soils of the Prairie Provinces. The natural vegetation is woodland. The soils are less productive and not so suitable for grass production. The typical soils under wooded conditions have a grey leached ash-like layer near the surface, immediately below a thin dark leaf mould. The lime layer is usually encountered between 2 and 4 feet below the surface.

In Southern Ontario and South-Western Quebec the soils are variable but in the main have developed under a humid climate and a vegetation of deciduous forest. The grey-brown podsolic soil usually has a thin dark surface layer over a greyish-brown leached layer which rests upon a darker brown layer. Black muck and peat are often found in poorly drained depressed areas of this region.

Farther east in South-Eastern Quebec and the three Maritime Provinces lies the podsol soil zone. This is characterized as a leached acid soil which under undisturbed conditions has a distinct, ash-like layer near the surface, below the leaf mat, and has a brown to reddish-brown or red sub-surface layer. The ash-like leached layer may vary from 1 to 12 inches in depth. These soils are usually less fertile than the grey-brown podsolic soils and are improved considerably by applications of manure and commercial fertilizers. The soils are usually acid and respond to treatment with liming materials.

Much of the land in Northern Canada is rough, rocky and unfit for agriculture and in the far north tundra soils prevail. These are not important from an agricultural standpoint.

Ecological and Regional Distribution of Pasture Species

Closely associated with the climatic and soil conditions affecting the productivity of pastures in Canada are the variations in plant species. For example, the species dominating Ontario pastures is Kentucky bluegrass. Red top and red fescue are the most common in Quebec, while brown top is most prevalent in the Maritime Provinces. In the Prairie Provinces there are no clearly defined areas of pasture species. In an ecological and grazing capacity study made in Alberta, Saskatchewan and Manitoba by Clarke and others (Canada, 1942) there were found over 1100 species representative of 426 genera and 112 families.

The presence of certain plants in the pasture is often taken as a reliable indication of the condition of the pasture. Pastures consisting largely of brown top as in the Maritime Provinces are readily converted to Kentucky bluegrass and other species when fertilizing and liming have improved the fertility levels. Likewise the reversion to a natural state after having been broken and reseeded follows through a definite succession of species. The species of grasses and legumes that are grown extensively in Canada are not numerous, but they are highly adapted to the rather exacting climatic and soil conditions of a particular area.

It is not the purpose of this bulletin to discuss in detail the native species occurring in the unimproved pastures, but rather to deal with the species that are commonly used in seeding down new pastures. Before discussing species of grasses and legumes for specific purposes, it appears to be in order to know something about their general behaviour from the hay and pasture standpoint. The brief facts in the following paragraphs are based upon data accumulated over a period of years from different experiments designed for this purpose.

Grasses

Timothy: *Phleum pratense* L. This is the most widely adapted of all the grasses. It grows well in association with a number of legumes commonly seeded for hay and for pasture purposes. It is fairly winter hardy, although a relatively short-lived shallow-rooted grass. It is not particularly drought resistant, being better adapted in regions with moderate rainfall. It is particularly suited to heavier soil types. The seed is relatively cheap, and should be included in making up most pasture mixtures.

Kentucky bluegrass : *Poa pratensis* L. This grass is the dominant species in natural or untilled pastures on non-acid soils, particularly in Ontario and Quebec. On such grasslands it is quite aggressive and persistent and competes with most other species. By itself, Kentucky bluegrass is relatively unproductive and certainly not as palatable as many other grasses that may be seeded for pasture. However, due to its ease of establishment and persistence, this species is often used as a " bottom grass " to act as a filler and with proper fertilization and combination with legumes a small amount may be included when seeding down to permanent pasture. Kentucky bluegrass makes a good sod and can withstand heavy grazing. It makes its most rapid growth for a few weeks only in May and June, after which it matures and remains more or less dormant until revived by fall rains and cooler weather.

Canada bluegrass : *Poa compressa* L. This is the dominant species in certain sections of Ontario. It is better suited than Kentucky bluegrass for locations subject to drought, such as are usually found on some of the light sandy soils. Shallow soils over rock or shale are very often covered by Canada bluegrass, which grows well in the early spring when soil moisture is plentiful and then goes into a dormant stage through the summer. As a pasture grass it compares favourably with Kentucky bluegrass in yield and chemical composition, and it is considerably more palatable. Canada bluegrass does not form so dense a turf as Kentucky bluegrass, unless moisture is the limiting factor. This species is not used to any extent when seeding down new pasture mixtures.

Red top : *Agrostis alba* L. This grass is sometimes included in mixtures to provide good " bottom " in the pasture. Should certain less hardy species kill out, red top quickly takes possession and may even crowd out all other species. It is less palatable and less nutritious than some of the other grasses and the amount seeded in a mixture for pasture should not be very high.

Colonial bent (brown top) : *Agrostis tenuis* Sibth. This grass is dominant on much of the grassland in the Maritime Provinces, especially on those soils which are deficient in lime. Under these conditions it is productive and of fair quality if reasonably well grazed. It is generally associated with wild white clover which can usually be increased with appropriate fertilization and suitable grazing management. It is never necessary to sow colonial bent on land well adapted to this species as it grows freely from seed which is present in the soil. On soils which are not highly adapted to this species, it would be unprofitable to include it in the pasture mixture as better grasses are available.

Red fescue : *Festuca rubra* L. Of the small fescues including Chewing's fescue (*Festuca rubra* var. *fallax*), sheep's fescue (*F. ovina* L.) and creeping red fescue, the last named is most important for pasture purposes. Like Kentucky bluegrass, Canada bluegrass and red top, it is essentially a " bottom grass." Creeping red fescue when seeded alone is not a very productive grass nor is it very palatable under our conditions. Seeding it in a pasture mixture helps to thicken up the sward and provides considerable herbage ; the grass is then more readily eaten along with other grasses and legumes.

Meadow fescue : *Festuca elatior* L. This is a tall-growing and broad-leaved species of fescue which thrives well in certain areas, particularly Western

Ontario. It is sufficiently winter hardy for practical purposes, although it winter-kills occasionally. Meadow fescue is palatable and grows well in association with other grasses and legumes that are not grazed too closely. Like timothy, it prefers rich, moist soils and does not do so well on sandy land or in dry locations. This grass has a place in short-term pastures and the addition of a few pounds of seed per acre is often advantageous.

Brome grass: *Bromus inermis* Leyss. This grass is hardy, possesses good sod-forming habit but is not equal to crested wheatgrass in this respect. It is productive, palatable and high in nutritive value, and is very widely used in hay and pasture mixtures in Western Canada where it is particularly well adapted. It has only a limited use in Eastern Canada, although recently it is being more widely grown in Western Ontario and the Ottawa Valley in Ontario. Being a fairly tall-growing, leafy and hardy species, brome grass grows well in association with alfalfa for hay or for pasture.

Crested wheatgrass: *Agropyron cristatum* L. This is a hardy bunch grass which excels most grasses in drought resistance under conditions such as obtain in Western Canada. In such areas it produces a good quality of pasture for all classes of livestock. In Eastern Canada this grass is not nearly so well adapted as timothy, brome grass, Kentucky bluegrass, etc. Its use is definitely limited by climatic conditions and therefore it is chiefly used under range and prairie conditions in Western Canada.

Slender wheatgrass: *Agropyron pauciflorum* Schwein. This grass, also known as Western ryegrass, is a hardy but short-lived perennial. It is not as widely adapted as timothy in Eastern Canada, but in Western Canada it has been grown quite extensively. It is the most alkali-tolerant of all grasses and is thus a most suitable grass for moist areas that are slightly alkali and subject to ponding. In Western Canada, slender wheatgrass is somewhat inferior to brome grass and crested wheatgrass for pasture purposes.

Reed canary grass: *Phalaris arundinacea* L. A very vigorous grower, especially in wet soils such as bottom land subject to flooding and in peaty soils, this grass is exceptionally winter hardy and tolerant of soil acidity. Reed canary grass thrives also on upland soils with moderate moisture supplies. It is not yet widely used, chiefly because of scarcity and cost of seed. However, only a small amount of seed per acre is necessary when seeding down because this grass spreads rapidly by means of underground rootstocks. Reed canary grass is palatable to all classes of livestock, is a rapid grower, and yields well and should be included in a great many cases when seeding down pasture mixtures.

Orchard grass: *Dactylis glomerata* L. This grass makes a vigorous growth in the spring and is noted for the rapidity with which the aftermath is produced after cutting or grazing. It is not very winter hardy and is occasionally severely injured in Eastern Canada. In British Columbia this grass is sufficiently winter hardy for general use. Because of its rapid growth and ability of rapid recovery, and because of the amount of forage it produces, orchard grass may find a place in pasture mixtures where it is adapted to the soil. The more winter-hardy strains which are leafy and persistent under grazing are now being used more widely in Eastern Canada and British Columbia.

Other Grasses. There are only a few other grasses that are sometimes seeded under special conditions for pasture. Perennial ryegrass (*Lolium perenne* L.) is probably the most desirable of these grasses where it can be grown successfully. It is productive, palatable and thrives well in association with wild white clover. It lacks winter hardiness, however, and cannot be used as widely as most of the grasses described above. Under conditions such as are found in British Columbia, perennial ryegrass may be used, but in Eastern Canada this grass may prove useful only as an annual nurse crop in seeding down permanent pastures to be grazed in the seeding year. Only a few other grasses need to be mentioned here. These are meadow foxtail (*Alopecurus pratensis* L.), tall oatgrass (*Arrhenatherum elatius* L.), rough-stalked meadow grass (*Poa trivialis* L.) and Italian ryegrass (*Lolium multiflorum* Lam.). With the possible exception of meadow foxtail, these grasses are of minor importance in establishing new pasture in Canada.

Legumes

The most important consideration in making a good pasture is to secure and maintain a satisfactory mixture of grasses and legumes. Without legumes, most of the grasses are relatively unproductive, whereas if legumes are present in sufficient quantity the growth of the grasses is increased and the total yield and nutritional value of the herbage is greatly improved. It is, therefore, very important to select those legumes which are best adapted to the soil and climatic conditions and then endeavour to maintain them by suitable grazing management and fertilization. The most important pasture legumes in Canada are alfalfa, red clover, alsike, white clover, Ladino clover and sweet clover.

Alfalfa: *Medicago sativa.* Alfalfa has many qualities which make it of first-rate importance as a forage crop in Canada. It has the ability to yield well under a wide range of soil and climatic conditions. Alfalfa, although primarily a hay crop, makes excellent pasture in areas where trouble from bloating is not too serious. Grown in mixtures with grasses, alfalfa is palatable and it makes ideal pasture from the standpoint of total seasonal production and distribution of the yield. Alfalfa and mixtures of alfalfa maintain high yields during the summer months when grass pastures produce very little. In the Prairie Provinces mixtures of alfalfa and brome grass or crested wheatgrass are used extensively for pasture. In Eastern Canada alfalfa is used primarily for hay for 1 or 2 years to be followed by a year or more of pasture. Such pastures consistently produce higher yields than the mixtures of grasses and legumes without alfalfa.

Red clover: *Trifolium pratense.* This legume is very widely adapted in Eastern Canada and to some extent in British Columbia. It is commonly grown in a mixture with timothy as these species thrive particularly well together. In the year after seeding the herbage is composed mainly of clover, but in the second year the crop is mainly timothy. This is one disadvantage of red clover, and its use is limited to short rotations for hay or pasture. Early double-cut types of red clover are more commonly used in Canada, because they are best adapted for hay purposes, but if left for pasture only a small percentage of this legume persists more than 1 year. In certain areas, single-cut types are favoured because the plants are leafier and more perennial in habit

of growth. Red clover is very productive and palatable to all classes of livestock ; therefore some seed should be included in hay-pasture mixtures where this legume is adapted.

Alsike : *Trifolium hybridum.* Alsike is a high-yielding but short-lived legume. Like early double-cut red clover, it is suited only to short-rotation pastures. In certain sections of Eastern Canada, more especially in parts of Ontario, alsike largely replaces red clover. In other areas it is a common practice to include 2 pounds of alsike seed in mixtures of timothy and red clover. On certain soils, usually more or less deficient in lime, alsike thrives better than either red clover or alfalfa. For this reason the inclusion of some alsike in the mixtures is generally believed to provide a more uniform stand of clover, and to increase the yield to a greater or lesser extent depending on its degree of adaptation to the particular soil in which it is being grown.

White clover : *Trifolium repens.* White clover occupies a place of unique importance. From a sprinkling of inconspicuous plants it is often possible, by the application of phosphatic fertilizers and appropriate grazing management, to secure a rapid development of the clover to a point where it makes up a substantial proportion of the herbage. White clover is essentially a pasture plant and is widely used in pasture mixtures. It thrives under a wide range of soil types and conditions. It spreads and persists by means of creeping stolons. It is less sensitive to climate than red clover, and thrives best in a moist but well-drained soil, particularly when there is ample lime and humus. While it needs warmth and moisture, it withstands drought better than red clover, although even in Eastern Canada it is severely checked by the hot and dry weather in July and August. White clover is unexcelled for closely grazed pastures when in a mixture of grasses adapted for this purpose. It has been found that where white clover grows well in association with grasses it more than doubles the yield of pasture herbage and produces about five times as much protein per acre as grasses grown without clover under similar conditions. The most common type of white clover is the wild, native clover found in old uncultivated pastures. Due to the importance of white clover in pasture mixtures, common white Dutch and other varieties such as New Zealand Wild White, English Wild White and Danish strains are being more and more widely used. Ladino, Mammoth or Giant White Clover, differs from the other clovers mentioned above. It is slightly later-flowering than white Dutch and is larger than that variety in all its parts. It is more persistent under certain conditions than white Dutch. It is no more tolerant of wet soil conditions than common white clover, but will thrive under conditions suited to alsike and where red clover and alfalfa often kill out. Under such conditions it usually yields more than alsike. For this reason it is being more and more widely used in hay-pasture mixtures in Eastern Canada and British Columbia where white clover is fairly generally adapted.

Sweet Clover : *Melilotus alba* is a strong, vigorous biennial legume. It is rather bitter, coarse and is quite persistent in lighter soils and waste places in Canada. It is not grown to any extent for pasture if any of the legumes described above are adapted to existing conditions. However, sweet clover has a place in certain areas, particularly in Western Canada, where alfalfa, red clover or alsike are unproductive, because of lack of winter hardiness or for

other reasons. If the pasture is well managed, sweet clover will produce a surprising amount of forage of excellent quality.

Pasture Management in Eastern Canada and British Columbia

Untillable pastures. Large areas throughout Eastern Canada and British Columbia are too hilly or stony for cultivation. Except on the heavily forested sections of such areas, it is customary to utilize the land as much as possible for pasture. Improvement of such pastures has been recommended and considerable progress has been made in this direction. One of the first steps in improvement is to eradicate as much as possible of the undesirable growth of small shrubs and weeds. Where the land surface is not too rough or irregular this may be done with a mowing machine. On very rough ground a hay scythe or short-bladed brush scythe may be used. For some of the larger shrubs it may be necessary to use an axe or mattock. The most satisfactory time to cut the shrubs is in late summer or fall. Weeds should be kept cut to prevent the formation of seeds.

Where the sward is very thin and very little grass or clover is present, it is often possible to improve the stand of herbage by broadcasting a seeds mixture of (in pounds per acre) : orchard grass 4, red top 2, timothy 8, white clover 1, sweet clover or red clover 6. The soil should be stirred immediately after seeding with a disk, spike-tooth or brush harrow in order to provide some covering for the seed. To be successful the work should be done in the very early spring while the ground is soft and moist.

Production can often be increased on these rough pastures by the judicious use of commercial fertilizer. The amount of fertilizer and the formulæ will depend on the fertility of the soil and the type of sward. Where wild white clover is indigenous, an application of 400 to 500 pounds of superphosphate (20 per cent.) every 3 or 4 years may prove economical. On predominantly grass swards, 500 pounds of a 2-12-6 or 4-12-6 fertilizer per acre every 3 years will often give good results. If available, barnyard manure may be topdressed on the pasture. Usually, however, manure is used on more productive areas of cultivated crops.

Permanent pastures which are tillable. Many areas of permanent pasture are located on land which is tillable. In parts of Ontario and Quebec these areas may be located on land which is rather inaccessible or poorly drained, or perhaps labour supply may force the owner to resort to this method of labour-saving farming. In the Maritime Provinces and parts of Quebec, however, where soil and climate are more favorable, this type of pasture thrives and by proper treatment may be the most productive and remunerative area on the farm. The productivity of such pastures may be maintained and often improved by suitable cultural practices, the use of commercial fertilizers and manure, and by careful management of the pasture.

Usually such pastures have a reasonably good cover of grass and clover of a species native to the particular district. Where this is true little is to be gained by cultivating or reseeding. The area should be mowed once or twice each year to cut off any undesirable growth which may appear. The pastures should be harrowed occasionally to spread animal droppings. In general this type of pasture should be grazed closely if the grass is to be utilized to best

advantage. This can be overdone, of course, in regions of high temperatures and rapid evaporation where rain is rather intermittent and close grazing exposes the soil to rapid drying with a resulting check in plant growth.

For maximum production the fertility should be built up to a relatively high level. This can usually be done most efficiently by the use of commercial fertilizers. Fertilization is similar to that for untillable pastures, but as a rule the tillable pastures are more productive, and in the main higher rates of fertilizer may prove economical. Here again the type of soil and sward will govern the application.

On clay soils where clovers are prevalent, 500 to 600 pounds of superphosphate per acre every 3 years may prove economical. On the lighter soils an 0-14-7 or an 0-16-10 at the same rate may be necessary. Where grasses predominate 600 pounds of a 4-12-6 fertilizer per acre every 3 years is recommended, and on the lighter soils the rate might be increased slightly and more potash added to make a 4-12-10 mixture.

Where the sward has become very thin and weedy it may be necessary to plough and reseed an area. The land should be ploughed in August to allow for cultivation to eradicate weeds. Cultivation should be frequent during the remainder of the season. In the late fall, manure if available should be applied at the rate of 12 to 15 tons per acre and well disced into the soil. If more convenient this may be done in the spring. In the early spring the land should again be thoroughly cultivated to provide a seed-bed. If manure has been applied, a dressing of 300 pounds per acre of superphosphate may be broadcast on the soil and harrowed in just before seeding, or it may be drilled in with a combination grain and fertilizer drill when seeding. If no manure is applied, the fertilizer should be made up of 500 to 600 pounds of a 2-12-6 mixture applied as outlined above.

The permanent pasture seed mixture is usually seeded with a light nurse crop of wheat, oats or barley which may be grazed later or cut for hay or grain. The grass and clover mixtures recommended are as follows (rates in pounds per acre) :—

1. Seeds mixtures where alfalfa can be grown successfully : timothy 8, red clover 3, alfalfa 4, alsike 1, Kentucky or Canada bluegrass 3, red top 2, and wild white clover 1. Total = 22 pounds per acre.
2. Seeds mixtures for acid soils to which alfalfa is not adapted : timothy 8, red clover 5, alsike 3, Kentucky or Canada bluegrass 3, red top 2, and wild white clover 1. Total = 22 pounds per acre.

The above mixtures are designed for use as hay the first year or two after seeding, following which the bottom grasses and clovers develop and make excellent pasture. Where it is desirable to establish a permanent pasture for immediate grazing, the following seeds mixture is recommended without a nurse crop (rates in pounds per acre) : Kentucky bluegrass 5, Canada bluegrass 5, perennial ryegrass 5, timothy 6, and wild white clover 2. This mixture may be seeded broadcast on land prepared as above and the seed covered lightly with a harrow. Grazing may begin in about 8 weeks after seeding and continued during the following year as for permanent pasture.

On acid soils an application of ground limestone at 1 to 2 tons per acre

applied previous to seeding the above mixtures is recommended. The limestone should be thoroughly worked into the soil. Lime applied in this way has given very good results whereas it often shows very little benefit when applied on top of a grass sward, although the latter method has also given good results on many pastures.

Pastures in a crop rotation. In the Maritime Provinces and parts of Quebec where improved permanent pastures are very productive, it is questionable if cultivated crops in a farm rotation for pasture are economical except where aftermath from hay or other incidental grazing may be utilized. In Ontario and Western Quebec, on the other hand, cultivated crops may be much more productive, and soil conditions and climate favor the production of corn, grain, red clover and alfalfa. Furthermore, permanent pastures in these regions fall off very seriously in production during July and August. Under these conditions many farmers find it more satisfactory, in fact in some cases essential, to grow all their pasture in the farm rotation of cultivated crop species, and have no permanent pasture whatever.

A portion of the rotation is thus set aside for pasture in which an alfalfa-grass mixture may form the bulk of the herbage, supplemented with an annual crop such as oats or oats and Sudan grass, hay aftermath, rape or any other incidental supplementary pasture which may be utilized or for which provision has been made previously. An alfalfa-grass seeds mixture which might be saisfactory for this purpose is (in pounds per acre): timothy 6, red clover 3, alfalfa 6, and alsike 1. Under conditions where they thrive well, brome grass, orchard grass or meadow fescue may be used to replace part of the timothy in the mixture. To obtain the maximum production, this crop should be harvested for hay for 1 or 2 years following seeding after which it may be used for pasture.

Annual or supplementary pastures

Under conditions which prevail in Eastern Canada permanent pastures and even pastures in a crop rotation are subject to a period of low production in midsummer. To prepare for this shortage of feed it is necessary to seed some annual crops. A crop should be selected which is adapted to the soil and climatic conditions of the district, and also consideration must be given to the season of the year in which the pasture is required.

In the Maritime Provinces and Eastern Quebec, oats alone at 3 bushels per acre may be seeded to be grazed from 4 to 5 weeks from the date of seeding. The oats may be seeded any time the land is ready, but not later than 10th to 15th June. While oats may be seeded alone it is often more desirable to seed them in a mixture of oats at 2 bushels and Sudan grass at 20 pounds per acre. This mixture may be seeded about the end of May. The oats grow better in the cool conditions of the spring and will provide early pasturage, while the Sudan grass will provide grazing later in the season. When this mixture is used as a nurse crop, the rate should be reduced to 1·5 bushels of oats plus 15 pounds of Sudan grass. Sudan grass, however, must have conditions similar to corn and will not thrive in cold, heavy, poorly drained soil; for this reason it is not recommended as generally as oats for this purpose. In Western Quebec and Ontario, Sudan grass at 25 to 30 pounds and millet at 20 to 25

pounds per acre have been grown successfully for pasture. Some of the varieties of millet commonly grown are: Empire, Japanese, Siberian, Crown and Common.

Oats at 2 bushels and sweet clover at 15 pounds per acre are sometimes seeded for summer pasture. If not grazed too severely, the sweet clover will provide some additional hay or pasture in the following year.

Rape seeded at 3 to 5 pounds per acre up to 1st July will provide very good pasture in 8 to 10 weeks after seeding and is excellent for sheep, hogs and beef cattle.

Other annuals that may be used for pasture are: fall rye alone seeded in the fall for late fall and early spring grazing, soybeans in drills or broadcast, kale seeded similarly to rape, and/or a thick planting of corn.

Oats at 2 bushels and fall rye at 1 bushel per acre seeded early in the spring will provide considerable pasture in certain areas. There are many other crops that may be grown to good advantage with oats for pasture. Spring rye, millet and Italian ryegrass are sometimes used for this purpose.

The aftermath from meadows should not be overlooked. Usually this will provide additional pasture during the late summer and early fall periods, and at a time when permanent and rotational pastures are relatively unproductive.

Pasture Management in the Prairie Provinces

Rangelands. The largest area of grazing land in the Prairie Provinces is that section which lies in the drier, southern portion of South-Eastern Alberta and South-Western Saskatchewan and comprises the great ranch country or rangelands of Western Canada. The area is made up of approximately 35 million acres. Here the native short grasses survive because of their ability to resist drought. The production is not high and the true grazing capacity of the area is about 30 acres per animal unit. The area requires and receives very little attention from the standpoint of management. As moisture is the limiting factor, fertilizers have no value in promoting production. Only a few drought-resistant grasses will grow satisfactorily and thus improvement in the way of reseeding with new species is limited. The management, therefore, consists largely of providing fences to keep the livestock within bounds, the provision of proper watering facilities and supervision to prevent overgrazing.

In some cases overgrazing has occurred and desirable grass species have been killed out and replaced by weeds and bare ground. In other instances the land has been broken in an effort to grow wheat. In much of this area subsequent experience has shown that wheat cannot be grown successfully and the attempt has been abandoned. Such areas are best reseeded to rangeland and in recent years individuals and governments have done much to reclaim them.

Crested wheatgrass is the best grass available for the regrassing of abandoned fields and depleted range pastures. After a field has been abandoned it is well to seed it to crested wheatgrass as soon as possible although it may be seeded successfully even in a dense stand of weeds. The most suitable time for seeding is the late fall just before the ground freezes, so that the seed will not germinate until the following spring, or in early September if there is sufficient moisture at the time. Spring seeding is also

satisfactory provided it is done very early. The seed should be drilled into the ground among the stubble or weed cover to prevent soil drifting. The pressure springs on the seed drill should be regulated to place the seed about one half-inch deep. No previous cultivation is necessary unless the surface soil is baked and cracked, in which case a single discing before seeding is advisable. The seed may be sown in drills 6 inches apart at the rate of 10 pounds per acre or in rows 12 inches apart at 6 pounds per acre. A mixture of 5 pounds of crested wheatgrass and 2 pounds of alfalfa per acre will sometimes give good results. No nurse crop is recommended, but where the soil is bare and likely to drift a crop of rye or some other cereal should be sown first in order to have a stubble cover into which to seed.

In some areas brome grass is satisfactory for reseeding and may be seeded alone at 10 to 14 pounds per acre. In low moist areas, a mixture may be used composed of alfalfa 4 pounds and brome grass 6 pounds per acre. Still another mixture which is recommended where the growing of alfalfa is hazardous is made up of sweet clover 6 pounds and brome grass 8 pounds per acre.

In sloughs or flood areas reed canary grass at 4 to 6 pounds per acre will give good results.

Pasture on farm lands. Farther north in the park belt and grey wooded soil areas of the Prairie Provinces some mixed farming is practised, and on these farms approximately 1,579,000 acres are in pasture of several years' duration. Such pastures are sometimes grown in the farm rotation in which summer fallow may be followed by wheat and then oats, subsequently seeded to hay or pasture and left for 3 to 4 years. In some cases the pastures are seeded on a permanent basis.

Proper preparation of the land before seeding is important. The soil should be firm in order to prevent too deep seeding and should be protected against possible soil drifting. For fall seedings it is important to have a stubble, trash or weed covering. In the drier areas it is advisable to seed directly into the grain stubble. In regions of higher precipitation the seeding may be done on well-packed fall or spring ploughing. On newly-broken land it is better to grow grain crops for a year or two before seeding down. In sections where irrigation is practised the land should be levelled and the necessary dykes and ditches built before seeding, since pasture requires frequent irrigation. Grasses may be seeded in the late fall, legumes usually give better results when seeded in the spring. The seeding should be done about one half-inch deep without a nurse crop, although if seeded at a reduced rate per acre a nurse crop may be used in the moister areas. The most satisfactory method of seeding is in drills with a grain drill. Broadcast seeding is not recommended.

Manure if available, applied in the fall or during the winter at 10 to 12 tons per acre, will usually increase the production of pasture particularly in the more moist areas, on grey wooded soils or on irrigated land. The manure should be thoroughly worked into the soil before seeding or may be applied as a topdressing on the established sod. In the latter case the manure should be harrowed in order to promote even distribution over the pasture. Commercial fertilizer is not used to any appreciable extent in pastures in the Prairie Provinces. On the grey wooded soils in the northerly sections, however,

an application of 40 to 60 pounds of ammonium sulphate or ammonium phosphate (16 to 20 pounds) will often give a marked increase in production.

A considerable variety of seed mixtures has been recommended for this area of the Prairie Provinces and includes for the drier sections 6 pounds per acre of crested wheatgrass in drills 12 inches apart. As moisture conditions become more favorable farther north, the rate of seeding may be increased by a few pounds and seeding may be done in drills 6 inches apart. Brome grass at 12 pounds per acre will thrive in areas of higher moisture. In the more favorable regions 2 pounds of alfalfa per acre may be advantageously mixed with the grasses.

In the park belt or grey wooded soil area where moisture conditions are in general more favorable, 9 to 12 pounds of crested wheatgrass and 3 to 4 pounds of alfalfa may be used in the drier areas. Under more moist conditions 10 pounds of brome grass and 3 to 5 pounds of alfalfa is satisfactory. Timothy may sometimes be used instead of brome grass. For a more permanent pasture in the most favorable sections the following mixture is recommended: brome grass 8, alfalfa 4, Kentucky bluegrass 4, and white Dutch clover 2 pounds per acre.

Management of cultivated pastures. Livestock should be turned on the pastures as early in the spring as the condition of the land and growth of grass will permit. The principal grasses should be about 4 inches tall when grazing starts. Pastures should not be allowed to become too mature at any time since they become less palatable and nutritious with advancing maturity. On the other hand too close grazing, especially in the early spring, will often result in a general deterioration of the pasture. Weeds should be controlled by occasional mowing and bare or weedy patches should be reseeded when a favorable time for seeding occurs.

Annual or supplementary pastures. Annual crops for pasture play an important part in supplying additional feed for livestock at the time when perennial crops are relatively unproductive. In the Prairie Provinces annual crops are a dependable source of forage, one year with another, provided they are grown on land which has a certain amount of reserve moisture. Grain crops seeded reasonably early in the spring usually provide excellent pasturage from the time they are about 6 inches high.

Under most conditions oats are superior to the other annual crops. Oats recover better after grazing than most other annuals and therefore yield higher. A mixture of about one bushel each of oats and fall rye sown in the spring provides a very productive pasture.

The beardless and smooth-awned varieties of barley are often used for early summer pasture. Wheat or spring rye may be useful in some cases, the latter being particularly useful on poorer sandy soils and quite early.

Millet is a rapid-growing, short-season, annual crop, but one which is very susceptible to frost and must be seeded after the danger of spring frost is past. It is particularly valuable for seeding late in the spring after some other crop has failed. The foxtail types of millet are superior to the broom corn or proso types for forage. The usual rate of seeding millet is around 15 to 20 pounds per acre on well-prepared and warm soil such as is required for good growth of corn.

Other crops that are sometimes used for annual or emergency pastures are: Oats at 1 to 2 bushels and sweet clover at 15 pounds per acre, oats at 2 bushels and rape at 3 pounds per acre; rape alone at 4 to 5 pounds per acre if broadcast, or 2 to 3 pounds per acre if in rows. Rape is particularly useful for late fall pasture since it is not readily injured by frost. Kale is frequently used in place of rape for finishing lambs in the fall or for pig pasture. Seeded when the ground is suitable for sowing grain in the spring until the latter part of July, kale or rape will be ready for pasturing in 6 to 8 weeks. Fall rye alone seeded as early as 1st August at 2 bushels per acre provides late fall pasture if moisture conditions of the soil are adequate. If seeded after 1st September, fall rye does not give any pasture until the following spring.

Reference

Canada, Department of Agriculture. 1942. Pub. No. 738. Tech. Bull. 44. An ecological and grazing capacity study of the native grass pastures in Southern Alberta, Saskatchewan and Manitoba. By S. E. Clarke, J. A. Campbell and J. B. Campbell. pp. 31.

Introduction

The sown pastures of Australia are mainly confined to the south and the east coastal plains ; the eastern highlands and their western slopes extending from Victoria to Queensland ; the north, west and midlands areas of Tasmania ; the Mount Lofty ranges and lower south-east of South Australia ; the south-western coastal and sub-coastal zone of Western Australia ; and the irrigation areas developed and being developed on the vast alluvial plains of the Murray and Murrumbidgee River system in northern Victoria and south-western New South Wales.

The gross area over which climatic conditions may be suitable for pasture improvement has been estimated to be no more than 600,000 square miles, or approximately one-fifth of the total area of the continent (Davies, 1940). The proportion of this area which has been sown to pasture is very small, the percentages for the various states being : Victoria, 7·02 ; Tasmania, 5·08 ; South Australia, 2·19 ; Western Australia, 2·84 ; New South Wales, 2·73 ; Queensland, 0·94 (Christian, 1944).

The Pasture Environment

Ecological factors

The total annual rainfall, and its seasonal distribution, are the two most important factors influencing the scope for, and methods of, pasture improvement. The total annual rainfall where sown pastures are grown varies from 15 inches in Southern Australia to over 140 inches per annum on the tropical north-east coast of Queensland. The seasonal distribution ranges from the reliable autumn-spring incidence of the Mediterranean climate of the southern littoral, through varying degrees of erratic non-seasonal rainfall, to an extreme summer incidence in the north (Table 1).

The line of equal summer and winter rainfall runs north of Carnarvon in Western Australia in a generally slightly south of east direction to cut the east coast of New South Wales near Sydney (Taylor, 1918).

South of this line, precipitation is primarily of the winter rainfall type. In Gippsland, Central Victoria and Tasmania, which lie in the east of this major region, moist soils are commonly experienced throughout the year and pasture growth is not infrequently maintained throughout the summer. The peak growth period occurs in November and December. Progressively westward through Victoria, South Australia to Western Australia, the period of influential rains contracts to a more distinct Mediterranean winter rainfall climate and the summers become increasingly long, hot and dry, peak growth being in September and October. This general trend, however, is modified by local physiography and proximity to the coast and the even trend is abruptly broken by the great expanse of the arid featureless and scarcely inhabited Nullabor Plain.

To the north of the line of equal rainfall distribution, the trend of summer incidence becomes progressively more marked and winter forage crops and pasture plants are gradually replaced entirely by summer-growing species. This main trend is again broken by local topography and altitude which tend to increase the total annual rainfall and, parallel with it, the aggregate winter

TABLE I

Stations in the Sown Pasture Belt of Australia: Monthly Mean Rainfall in Inches

Station	Location	Latitude S.	Month											Annual Mean
			Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Cairns	Tropical coast, North Queensland	16° 55′	16·6	15·5	18·1	11·6	4·4	2·8	1·6	1·7	1·7	2·1	3·8	8·6	88·4
Bowen	Central coast, Queensland	19° 59′	10·4	8·8	5·8	2·8	1·3	1·6	0·9	0·7	0·8	1·1	1·3	4·4	39·9
Gympie	South coast, Queensland	26° 11′	6·8	6·6	6·2	3·4	2·9	2·8	2·1	1·8	2·1	2·7	3·1	6·0	46·6
Gayndah	Sub-coastal, South Queensland	25° 38′	4·8	4·3	3·1	1·4	1·6	1·9	1·4	1·2	1·6	2·3	2·8	4·1	30·5
Dalby	Sub-coastal, South Queensland	27° 32′	3·3	2·8	2·8	1·3	1·3	1·7	1·7	1·2	1·7	2·0	2·7	3·2	25·8
Lismore	North coast, New South Wales	28° 48′	6·3	6·5	7·5	5·0	4·6	3·6	3·6	2·5	2·5	2·5	3·6	4·3	52·4
Glen Innes	North Tableland, New South Wales	29° 44′	4·2	3·0	2·8	1·6	1·7	2·5	2·0	1·9	1·9	2·9	3·0	3·9	31·3
Orange	Central Plateau, New South Wales	33° 17′	2·6	2·4	2·6	2·1	2·8	4·3	3·3	3·3	2·9	3·0	2·6	2·7	34·5
Moruya Hd.	South coast, New South Wales	35° 53′	3·6	3·4	4·0	3·1	3·3	3·0	2·5	1·9	2·6	2·6	2·3	2·7	34·9
Urana	Wheatbelt, New South Wales	35° 19′	1·1	1·3	1·4	1·2	1·8	2·1	1·4	1·5	1·5	1·5	1·2	1·1	17·1
Wangaratta	North Victoria	36° 21′	1·2	1·4	1·7	1·3	2·4	3·2	2·8	2·4	2·3	2·3	1·6	1·9	24·3
Leongatha	South-east Victoria	38° 28′	2·5	1·8	3·0	3·3	3·9	3·9	3·5	3·9	4·2	3·9	3·0	2·9	39·54
Colac	Central Victoria	38° 24′	1·3	1·4	1·8	1·8	2·8	3·2	2·8	3·1	2·9	2·6	2·0	1·7	27·4
Donald	West Victoria	36° 22′	0·7	1·0	1·0	1·1	1·7	1·9	1·5	1·7	1·7	1·5	1·1	1·1	16·1
Clare	South, South Australia	33° 50′	0·9	0·8	1·0	1·9	3·0	3·4	3·1	3·1	2·8	2·2	1·3	1·2	24·5
Mt. Barker	South, South Australia	35° 04′	1·0	0·9	1·4	2·2	3·8	4·6	4·3	4·2	3·6	2·8	1·6	1·3	31·7
Roseworthy	South, South Australia	34° 05′	0·7	0·6	0·8	1·4	1·9	2·5	1·9	2·1	2·0	1·7	1·0	0·9	17·3
Bunbury	South-west coast, Western Australia	33° 18′	0·4	0·6	1·0	1·7	5·3	7·3	6·9	5·3	3·7	2·4	1·0	0·6	36·2
Katanning	Sub-coastal, south-west, Western Australia	33° 42′	0·4	0·6	1·0	1·2	2·4	3·0	3·1	2·4	1·9	1·6	0·7	0·6	18·7
Stanley	North-west Tasmania	40° 47′	1·7	1·6	1·9	2·9	3·5	4·5	4·3	3·8	3·4	3·3	2·4	2·5	35·6
Oatlands	Midland Tasmania	42° 18′	2·0	1·4	1·6	1·8	1·7	2·2	1·6	1·6	1·7	2·2	1·8	2·2	22·0

Evaporation from a free water surface is given for the locations below:

Location	Rainfall inches	Evaporation inches	Latitude S.	Location	Rainfall inches	Evaporation inches	Latitude S.	Location	Rainfall inches	Evaporation inches	Latitude S.
Perth	34·90	66·17	31° 57′	Melbourne	25·64	39·11	37° 49′	Alice Springs	10·57	97·21	23° 38′
Adelaide	21·17	55·65	34° 56′	Hobart	24·08	31·32	42° 53′	Dubbe	21·85	66·37	32° 18′
Brisbane	44·91	56·15	27° 28′	Canberra	23·30	53·42	35° 20′	Laverton, West Australia	9·10	145·17	28° 40′
Sydney	46·90	39·86	33° 54′	Coolgardie	10·22	85·37	30° 57′				

rainfall. Thus the use of winter-growing species extends farther to the north on the highlands than on the coast or inland of the main range.

Within the limits of suitable rainfall, temperature is rarely a limiting factor, but in minor areas of the southern highlands and Tasmania prolonged periods of low temperatures do occur. Throughout the sown pasture areas, optimal soil temperatures for germination and establishment are the rule for extended periods.

Evaporation is high in the summer rainfall region and also in the drier parts of the winter rainfall region. Rapid drying of the surface soil, following apparently good sowing conditions, is thus not infrequent and can often be limiting to establishment, especially where rainfall incidence is more erratic. For more detailed information on Australian climatology the reader is referred to Griffith Taylor (1918) and to the summaries in Kendrew's *Climate of the Continents* and in the Commonwealth of Australia Year Books.

No attempt will be made to describe the wide range of Australian soils and the reader is referred to Prescott's *Soils in Relation to Climate and Vegetation* (1931). In general it may be said that the higher winter rainfall areas have a high proportion of podsolized soils, generally deficient in phosphate and frequently of low fertility. In the absence of suitable tropical and sub-tropical pasture legumes, sown pastures of the summer rainfall region are grown on the more fertile soils only.

Land use

Land development in Australia is still largely in the pioneering stage and grazing is mainly on an extensive scale. Pasture species are often required to colonize new but incompletely cleared forest or scrub lands, older clearings on which native swards have developed, or extensive areas of savannah or open grasslands. They must therefore show vigorous establishment, under poor seed-bed conditions, often on soils of low fertility, and in the face of heavy competition from regenerating scrub or forest species, understorey shrubs, or perennial grassland plants.

Sown pastures rarely occur as part of well-defined crop rotations. Even in the well-developed dairying districts, permanent pastures are the rule and the short-term leys common to European agriculture play a minor role. In sheep and beef cattle country the short-term ley is almost entirely absent and the sowing down of pastures is directed toward the production of permanent swards. In the wheat areas, however, the necessity for the introduction of stock into farm practice has led to the use of simple seeds mixtures of self-regenerating annual species, which are designed to provide pasturage for 1 to 3 years only, or of short-term swards of lucerne.

Undoubtedly, the need is for greater use of the short-term leys in Australian agriculture, in better defined crop rotations. At present their use is restricted to:—

(1) the production of meadow hay in the richer dairying districts,
(2) the renovation of sod-bound *Paspalum* pastures,
(3) the rehabilitation of overcropped, summer cereal lands and of horticultural areas,
(4) the production of supplementary summer grazing for dairy cattle by the use of such annual grasses as Sudan grass and the millet grasses.

Land Preparation

Pioneer pastures

The forest lands of the higher rainfall fringe of the continent and the tropical and subtropical scrub are cleared for the sowing of pastures by cutting, ringbarking and poisoning, or a combination of these, followed by burning of the timber. This process leaves a residuum of stumps and logs which preclude the use of even heavy-weight ploughs, and the pastures are sown immediately by broadcasting the seed on the ashes which form the seed-bed.

In the case of certain low-growing scrubs, heavy rollers are used to break down the growth which is burnt when dry. It is frequently possible to follow with heavy stump-jump disc ploughs and to prepare a rough seed-bed.

Planting on natural pasture

Trees of the savannah woodland are ringed and possibly poisoned, but ploughing is seldom resorted to for a number of years, during which period better pasture species are introduced by surface cultivation. This refers to the use of light disc ploughs, spring-tooth or rigid tine cultivators, or even heavy pasture harrows, to break the surface soil with the minimum disturbance of the existing tufty perennial pasture grasses such as *Danthonia* and *Stipa*. This practice, which is performed after the first autumn rains, is restricted to the region of winter species.

Pastures on primary cultivations

Improvement of older clearings of forest, savannah and savannah woodland, which were originally allowed to form swards without direct seeding, is commonly done in the winter rainfall zone by an initial fallowing and cereal cropping—oats being the main cereal used, though wheat is also used. The initial cereal crop may be used as a cover crop and the land returned immediately to pasture, in which case subterranean clover is the main component; but it is common to find one or two cereal crops taken, followed by field peas for grain or lamb fattening, the sown pasture mixture being sown either with or without a light cover crop of cereal. This latter method is an excellent preparation for the planting of the more permanent pasture mixtures based either on the perennial ryegrass/white clover or *Phalaris tuberosa*/subterranean clover mixture.

On older clearings of the brigalow and softwood scrubs of southern Queensland, cotton has also been used as the primary cash crop—and in some cases Rhodes grass (*Chloris gayana*) is sown after the final inter-row cultivation of the cotton in the second year, though seeding may be withheld until the following summer.

Pastures in crop rotations

Pastures may be introduced into crop rotations by sowing :—

(1) on fallowed land,
(2) on the stubble of a previous crop,
(3) with the final crop which acts as a cover crop,
(4) through a growing inter-row cultivated crop.

Fig. 22.—Pioneer pasture of subterranean clover established on ringbarked and burnt Jarrah forest country, Western Australia.

Fig. 23.—Early growth of Rhodes grass (*Chloris gayana*) broadcast on newly burnt ringbarked brigalow scrubland, sub-coastal Queensland.

Fig. 24.—Natural pasture of *Danthonia* on savannah woodland into which subterranean clover has been introduced by surface cultivation. North Victoria.

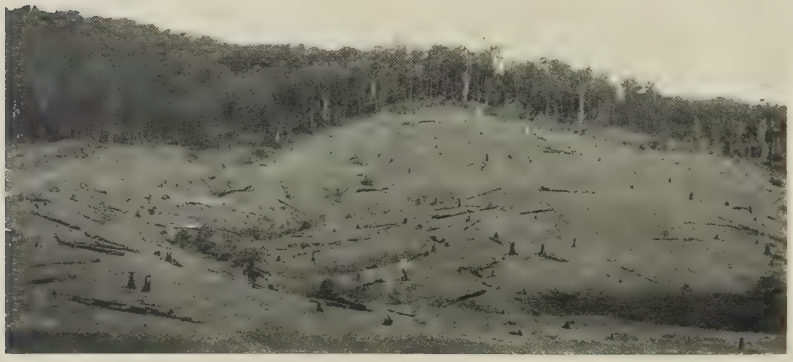

Fig. 25.—Pioneer clearing of rain forest, coastal Queensland, sown to *Paspalum dilatatum* and white clover after burning.

Fig. 26.—Savannah woodland, sown to *Phalaris tuberosa* and subterranean clover after primary cultivation, south-eastern highlands.

The preparation of land aims at producing a weed-free, well-consolidated seed-bed, with a surface layer of fine and "pebbly" soil. To achieve this, land is ploughed several months before sowing. It is then well worked down and kept weed-free by several cultivations. A final cultivation is invariably given after the first germinating rains to destroy the bulk of the germinating weeds. Loose soil may be consolidated with a roller or by running a flock of sheep over the land. An equally good seed-bed is often produced by surface cultivating the stubble of a winter cereal or summer fodder crop without fallowing. If grazed during the summer, such land is usually well compacted and relatively free of weeds. Either method is used to plant the pastures of the better rainfall areas of the winter region and those pastures of the drier areas based on perennial species. The self-regenerating annual pastures of the latter may be sown on land prepared by the second method or they may be sown with the last crop. The use of a cover crop is not always a good practice, but the inclusion of this type of pasture mixture with the last cereal crop, frequently oats for grazing, is a common procedure in the cereal districts. Lucerne is sometimes established, using low rates of seeding, in this way in the drier areas; but in general the competition for soil moisture offered by the cover crop seriously retards the development of the lucerne in all but the most favourable seasons, and the use of the cover crop is mainly advocated for medium and high-rainfall areas.

On the coast of New South Wales temporary pastures of Italian ryegrass and red clover are often sown through a growing crop of maize, and sometimes Rhodes grass and *Bromus unioloides* may be planted in the same way in Queensland. In neither case is any special land preparation made. The seed is broadcast through the rows following the last summer inter-row cultivation. A somewhat similar practice is the sowing of an annual grass such as Wimmera ryegrass through a thinning stand of lucerne. Preparation takes the form of a vigorous cultivation with a narrow tine cultivator after the early autumn rains.

Reference may also be made here to the preparation of poor or overcropped lands, from the point of view of soil fertility, prior to the establishment of perennial pastures. The spreading of farmyard manure on such lands is practised to a minor extent only, because no stock are housed in winter. The more common procedure is the growing, grazing and ploughing-in of either a summer-growing annual legume fodder crop, or a short-term grass-clover pasture mixture.

The renovation and re-establishment of old pastures

The *Paspalum*/white clover pastures of the east coast persist well, but become sod-bound and unproductive unless well cared for. A reduction in the proportion of white clover is accompanied by the invasion of the pasture by low-fertility-demanding species such as carpet grass (*Axonopus compressus*, Beauv.), blue couch grass (*Digitaria didactyla*, Willd.) and blady grass (*Imperata cylindrica* var. *Koenigii* R. & S.).

The rehabilitation of such pastures involves breaking of the tightly bound sod and the improvement of soil fertility. A common practice is to plough the pastures with a mouldboard plough in winter or spring, break up the turf

by thorough cultivation during the following summer and sow, with fertilizer, a temporary grass-clover pasture mixture in the early autumn. The *Paspalum* and " wild " white clover will quickly re-establish, but the opportunity is taken at this stage to introduce a superior strain of white clover with the temporary pasture mixture. Perennial ryegrass may also be introduced to the sward at this time in an attempt to maintain a more open type of sward, as well as to distribute production better.

In Queensland, Rhodes grass pastures of the sub-coastal belt deteriorate in consequence of frequent burning and continued stocking in the absence of an accompanying legume. These pastures will quickly re-establish, following a vigorous cultivation, but the stimulus provided is short-lived. Lucerne has been successfully introduced after surface cultivation of Rhodes grass pastures, but this practice is still in the experimental stage.

Irrigated pastures

Pastures for irrigation may be sown on well-cultivated and graded cropped land, on new land which has received a preliminary grading only, or on ungraded natural pasture land. As regrading may be necessary over a period of several years on some soils, new land is frequently cropped for that period or is sown down to a temporary pasture. Further cropping may follow before the permanent pasture is finally laid down. Preparation of land cropped in this way follows the usual methods of cultivation, with the addition of regrading. Where lucerne has previously been planted, thinning stands are often sown down to permanent mixed pastures and land preparation consists of ploughing followed either by a short-term fallow or the growing of a winter or summer cereal crop, depending on whether autumn or spring seeding of the pasture is intended. Seed-bed preparation may consist simply of a surface cultivation where friable soils are concerned and regrading is not required.

Pastures are most generally irrigated by flooding in bays enclosed by check banks placed at intervals of one-half to 2 chains. During the preparatory period, bays may be wider. The length of bay depends partly on the permeability of the soil, the type of pasture and the degree of slope. Bays vary from 5 to 20 chains long, but, in general, short bays are preferred for rapid and even distribution of water. For irrigating larger areas, such as improved natural pastures on which annual legumes have been stimulated by sowing and/or topdressing with superphosphate, the contour check system is becoming more common. A pre-sowing irrigation to permit reworking of the land to a satisfactory seed-bed condition, and also to wet the sub-surface soil in preparation for the germinating seed, is a common practice. After reworking to a shallow depth the seed is sown, awaiting autumn rains or, if necessary, a following irrigation.

Species and Strains

In the better rainfall areas of the south, Australia has made use of some of the widely used pasture species of European agricultures, such as perennial and Italian ryegrasses (*Lolium perenne* and *L. italicum*) and cocksfoot (*Dactylis glomerata*); red, white, strawberry and alsike clovers (*Trifolium pratense*, *T. repens*, *T. fragiferum* and *T. hybridum*). The use of lucerne for hay on

deep, fertile soils conforms to world practice, but the use of this deep-rooted legume in thin grazing stands in areas with low rainfall has also been extensively developed. Other species, of less renown in their countries of origin, have found suitable habitats in Australia and have become important sown pasture species. Outstanding amongst these are the annuals, subterranean clover (*Trifolium subterraneum*) and Wimmera ryegrass (*Lolium rigidum*), and the perennial drought-resistant *Phalaris tuberosa*, and to a lesser extent prairie grass (*Bromus unioloides*). In all cases, these plants have become naturalized after introduction and Australian ecotypes have arisen, differing widely from the species in their countries of origin. In Western Australia, on light, sandy soils of the coastal plain, and to a lesser extent inland, the self-regenerating annual, blue lupin (*Lupinus varius*), is of considerable local importance, commonly forming dense, almost impenetrable stands 5 to 6 feet high. Both sheep and cattle are grazed on the dried stands in the summer—the protein-rich seed being the main source of nourishment.

Perennial veldt grass (*Ehrharta calycina*), which has become naturalized in the vicinity of Perth, shows promise of becoming a valuable perennial grass on light soils in Western Australia and in the South Australian and Victorian Mallee.

Medicago tribuloides has been successfully used on moderately alkaline soils of the wheat belt in South Australia where the early varieties of subterranean clover are not vigorous. The African Rhodes grass (*Chloris gayana*) has become a most important species in subtropical Queensland, and the South American *Paspalum dilatatum* has become naturalized throughout the east coast region. On the tropical north coast of Queensland tropical perennial grasses find a suitable habitat and at least three of these, Para grass (*Brachiaria mutica* [Forsk.] Stapf), Molasses grass (*Melinis minutiflora*, Beauv.) and Guinea grass (*Panicum maximum*, Jacq.) are widely sown. An outstanding deficiency in the summer rainfall region is the absence of suitable pasture legumes. Practically throughout the better rainfall areas of the continent, Sudan grass (*Sorghum vulgare* var. *sudanense* Hitchc.) and Japanese millet are used as summer grazing swards. They are seldom sown with a legume and the swards last one summer only.

No native species has attained any important place in the sown pastures of Australia, although some effort has been directed to this end and a few species used to a minor extent. These are *Danthonia* spp., *Astrebla* spp., certain *Atriplex* species, notably *A. semibaccata* and *A. nummularia*. No native legume has been used.

Species in relation to the main pasture zones

Sufficient has been said regarding the pasture environment in Australia to indicate that it is extremely variable and, in consequence, in discussing species and mixtures in more detail, some classification of the continent in terms of climate and geography is necessary. Seven major regions in which pastures are sown may be recognized.

(1) The winter rainfall zone of Victoria, Tasmania, South Australia and Western Australia.

(2) The eastern wheatlands and drylands.
(3) The eastern highlands.
(4) The east coast.
(5) The tropical north-east coast of Queensland.
(6) Sub-coastal Queensland.
(7) The irrigation areas.

1. *The winter rainfall zone of Victoria, Tasmania, South Australia and Western Australia*

This zone is characterized by a predominant autumn-spring rainfall incidence, the summer rainfall varying from locations with considerable and reliable rains to those where conditions of almost complete aridity occur for periods ranging from several weeks to as long as 7 months. It is the duration and intensity of the hot, dry summer period which determine the choice of species and mixtures, and this zone can be subdivided in terms of length of growing season.

(*a*) *Long growing season.* Areas with fairly reliable summer precipitation and a total annual rainfall of 30 inches or more occur in south-east Victoria, in Tasmania, in the Mt. Lofty Ranges and lower south-east of South Australia, and in the south-west corner of Western Australia. In these areas conditions are ideal for European species such as perennial ryegrass, cocksfoot and white and red clover which are sown on cleared forest land. Rainfall is ample to carry perennial pastures, and soil fertility is the most important factor in the establishment and maintenance of pastures. Weeds are not troublesome in vigorous pastures, but if soil fertility is allowed to deteriorate, species such as Yorkshire fog (*Holcus lanatus* L.), sweet vernal (*Anthoxanthum odoratum* L.), sorrel (*Rumex acetosella* L.) and flatweed (*Hypochaeris radicata* L.) become established in the pastures. The most serious weeds of these zones, however, are bracken fern (*Pteridium aquilinum* Kuhn) and blackberry (*Rubus fruticosus* L.), and either one or both can rapidly overwhelm first-class pastures. Once established, control of these pests is very difficult, especially on dairying properties.

(*b*) *Medium growing season.* In the western districts and north-east of Victoria, Mt. Lofty Ranges and lower south-east of South Australia, central and eastern Tasmania, south-west of Western Australia and parts of the Southern Tablelands of New South Wales, there are areas with 22 inches to 35 inches annual rainfall in which summer conditions are severe for several months. These areas were mostly savannah woodlands with native pastures of *Danthonia* spp., *Stipa* spp., *Themeda australis*, *Microlaena stipoides* and *Eragrostis* spp., etc. Introduced species, such as white clover and cocksfoot, do not persist satisfactorily or remain productive under the more severe summer conditions experienced in these areas, except on specially favoured moist soils. Sown pastures are based on the use of the self-regenerating annual clover, *Trifolium subterraneum*. The choice of grass species is determined by local rainfall and soil type, and where suitable soil moisture relations are maintained through the summer, perennial ryegrass is grown in association with subterranean clover. Where, however, the initial soil fertility is too low to maintain perennial ryegrass satisfactorily, subterranean clover is grown on natural pasture for

several years and the perennial ryegrass is later introduced when soil fertility has been improved.

On lighter soils, or where the growing season is shorter, subterranean clover may be sown alone on natural pasture or in conjunction with the perennial *Phalaris tuberosa*, or the annual self-regenerating Wimmera ryegrass. The former is very drought-resistant and persists admirably through several months of dry, hot conditions, while Wimmera ryegrass will re-establish each year on self-mulching soil ; it tends to die out on heavier soils after the third year, but will remain productive longer if a light autumn cultivation is given. The aggressiveness of Wimmera ryegrass makes it possible to introduce it into natural pasture on rough cultivation. *Phalaris*, on the other hand, is slow to develop in its seedling year and must be sown on clean cultivated land and in the absence of strong competition from rapid-growing annual grasses and weeds.

Weeds of these pastures are mainly annual naturalized grasses, such as *Festuca bromoides* L., *Hordeum leporinum* Link, *Bromus hordeaceus* L., *B. sterilis* L., *Vulpia* spp. etc., and the miscellaneous weeds, Cape weed (*Cryptostemma calendulaceum*), crowfoot (*Erodium botrys* Bertol.), Salvation Jane (*Echium plantagineum*), Onion-weed (*Romulea parviflora*) and soursob (*Oxalis cernua*).

These species, which mature very early in spring and form useless and often obnoxious seed heads, and thereafter provide fodder of the poorest quality, are favoured by the rise in soil fertility induced by the continued growth of subterranean clover. Thus, wherever possible, sowings of subterranean clover are accompanied or followed by the sowing of a persistent perennial. Where it is sown alone on natural pasture, it is important that the native perennial species should be disturbed as little as possible, to minimize the entry of these poor annual species.

(*c*) *Short growing season.* Areas with 17 to 25 inches annual rainfall and a hot, dry summer period of 6 to 7 months occur widely in the central north of Victoria, the better red-brown-earth wheatlands of South Australia and in the savannah woodland area of south-west Western Australia. *Danthonia* and *Stipa* are dominant in the natural pastures. The persistent perennial native species are able to withstand the long severe summer. Cultivation in these areas is generally a direct result of wheat culture and much of the pasture establishment is on old wheatlands. These are discussed in the next section. Subterranean clover is, however, widely sown on natural pastures, both after ploughing and by surface cultivation.

2. *The eastern wheatlands and drylands*

The eastern wheatlands of Australia extend from the Darling Downs in Queensland through New South Wales, Victoria, to South Australia in regions of 20 to 30 inches annual rainfall in the north, and 10 to 25 inches annual rainfall in the south. The insecurity of wheat farming at the lower rainfall limits and the deterioration of the soil structure and soil fertility following continuous cultivation in all areas have led to the necessity for the adoption of mixed farming, hence the establishment of pastures on many cultivated wheatlands. The natural perennial species destroyed by cultivation are slow to re-establish and their place is taken by a number of inferior annual

species, notably barley grass, silver grass and *Erodium botrys*. The only sown species which can survive under the short growing season and low rainfall of the wheatlands are (1) annual self-regenerating species such as Wimmera ryegrass, subterranean clover (on approximately neutral or acid soils) and barrel medic (*Medicago tribuloides* Desr.) and a number of other naturalized Medic species * (on calcareous soils); (2) drought resistant deep-rooted perennial grasses such as *Phalaris tuberosa* and *Ehrharta calycina*; and (3) deep-rooted perennials such as lucerne or the non-legume *Oenothera latifolia*, but only if individual plants are widely spaced.

3. *The eastern highlands*

A series of broken mountain ranges, the Great Divide, extends along the east coast of Australia from Victoria to North Queensland. They assume their greatest importance in the southern half of the continent where they form the tableland of New South Wales, joining the south-eastern highlands in Victoria. In Queensland they are only of direct importance to sown pasture development in the south-east corner of the State and the area of the Atherton Plateau in the far north. The latter is similar in many respects to high rainfall areas at lower altitudes farther south, such as the subtropical coast. The major pasture species are *Paspalum dilatatum*, white clover, Rhodes grass and lucerne.

The tablelands of New South Wales receive an annual rainfall of 20 to 40 inches and the irregular topography and the wide range of soil types combine to create conditions of extreme variability so far as the use of pasture species is concerned.

The southern tablelands fall within the region of winter rainfall and at various places suitable habitats for all the winter rainfall species and mixtures are found, with those of the medium growing season pastures predominating. Lucerne is a common component of pasture mixtures, its use being conditioned by the relative proportion of summer rainfall.

On the central and northern tablelands the proportion of the total annual rainfall which falls during the summer months is greater, but with fair winter rains conditions are satisfactory for many winter species. *Phalaris* does exceptionally well in this area, and perennial ryegrass, white clover and *Medicago lupulina* are also well adapted to the heavier soils. Lucerne does well on well-drained soils and cocksfoot is satisfactory on the lighter soils where the rainfall exceeds 30 inches. In general, soil and climatic conditions do not favour subterranean clover, though it is used wherever practicable, its ability to regenerate from previous seedings after two or even three dry winter seasons being exploited.

4. *The east coast*

Dairying, with some beef fattening, are the major stock industries in this zone, which extends approximately from the New South Wales/Victorian border to Gladstone in Queensland. It comprises the river and coastal flats,

* The naturalized Medics, *Medicago denticulata*, *M. confinis*, *M. arabica*, *M. scutellata*, *M. orbicularis*, *M. laciniata* and others are important constituents of wheatland swards which develop without seeding on wheat stubble. They are seldom artificially sown.

the foothills and ridges adjacent to the river valleys and several small plateaux. Annual rainfall varies from 25 to 60 inches, with the proportion falling during the summer months increasing toward the north.

Soils consist of the fertile alluviums along the numerous rivers, the poorer podsolized soils on the slopes and hills, some poor granite soils and relatively small areas of fertile volcanic soils. *Paspalum*, which was originally sown on the better soil following clearing and burning of the timber, is not naturalized throughout the area. It is rarely sown, as where it is naturalized it readily invades most pastures. White clover is also naturalized throughout the area, but the species is less well adapted in the northern zone. Perennial ryegrass and cocksfoot are adapted to the southern portion of this zone. *Phalaris* has a wider adaptation, but its use is restricted to those areas with somewhat severe summer conditions. Kikuyu grass (*Pennisetum clandestinum*) is widely used in this zone but still only on a minor scale, probably because of the need for vegetative propagation. Italian ryegrass and red clover are extensively used as temporary pastures throughout the New South Wales portion and on the higher elevations on the Queensland coast. Lucerne is well adapted to the better drained soils, and apart from its use for hay it is also included in many pasture mixtures. Subterranean clover is sown only on relatively small areas of the drier country of the east coastal belt.

5. *The tropical north-east coast of Queensland*

With the exception of small areas on the tropical north-east coast of Queensland, no sown pastures have been developed in that part of Australia lying to the north of the Tropic of Capricorn.

Isolated islands of rain forest are found on the eastern coast, with rainfall varying from 60 to 140 inches per annum. *Paspalum dilatatum*, white clover and lucerne are all quite unsuited to these wet tropical conditions and only the more definitely tropical grasses such as Molasses grass (*Melinis minutiflora* Beauv.), Para grass (*Brachiaria mutica* [Forsk.] Stapf) and Guinea grass (*Panicum maximum* Jacq.) are used. There is no pasture legume available for these areas, but studies at the Bureau of Tropical Agriculture (Schofield, 1941) suggest that the aggressive perennial tropical legumes *Centrosema pubescens* Benth., *Calopogonium mucunoides* Desv. and *Pueraria phaseoloides* Benth. with *Stylosanthes guianensis* Sw., may become valuable grazing legumes in admixture with tropical and subtropical grasses. The self-regenerating summer-growing annual, *Stylosanthes sundaica*, Townsville lucerne, has become naturalized in certain areas, notably near Ayr and Mareeba. Its value as a tropical pasture legume remains to be assessed.

6. *Sub-coastal Queensland*

Pasture improvement in Queensland does not extend inland beyond the sub-coastal belt of southern Queensland. The minimum annual rainfall under which introduced species are planted is approximately 25 inches. In the 25 to 40 inches rainfall zone there is a large tract of Eucalypt forest with a grass flora in which the blue grasses, *Dichanthium sericeum* A. Camus, *Bothriochloa decipiens* C. E. Hubbard and *Bothriochloa intermedia* A. Camus, are characteristic species. Through this forest country there are scattered smaller areas of

scrubland of which there are two types, (1) the acacia scrub in which the most characteristic species is brigalow (*Acacia harpophylla*), and (2) the softwood scrubs which are akin to rain forest.

Much of this country was earlier invaded by prickly pear (*Opuntia* spp.) and it is only in recent years that this pest, which in many places prevented all forms of land utilization, has been successfully eradicated by introduced insect enemies. Rhodes grass is now grown extensively on the cleared scrubland soils and to a lesser extent on forest soils; it is virtually the only sown pasture species available, though small pockets of lucerne are grown on river alluviums where a water table exists.

7. *Irrigated pastures*

The major irrigation areas in Australia occur on the Murray River system in Victoria, New South Wales and South Australia, but there are a number of small schemes in all mainland States. Irrigated pastures are confined to the winter rainfall zone where irrigation water is used either to give grazing throughout the year for dairying, or to extend the growing season for fat lamb production, in those areas where rainfall is erratic or the rainfall season very short. Increasing attention is being paid to the value of irrigated pastures as supplements to natural pastures for wool growing, especially by Merino studmasters.

The pasture species used depend largely upon soil type, but the duration and reliability of the total water supply are important limiting factors.

Lucerne was the chief species in the early development of irrigated pastures in Australia, but it is now increasingly being replaced by perennial pasture mixtures based on perennial ryegress, cocksfoot and white clover. The summer-growing species, *Paspalum*, is also in common use because of its high summer yield, its ability to withstand heavy grazing and bad management, and because it can be grazed by heavy stock while land is still wet. It now successfully invades many sown pastures in the older irrigation settlements. Kikuyu grass is used to a minor extent.

Annual self-regenerating pastures are of particular importance in areas where water supply is restricted to spring and autumn and where soil fertility is relatively low. A mixture of Wimmera ryegrass and subterranean clover is also becoming increasingly used as a short-term ley in rotation with rice. Red and strawberry clovers, *Lolium italicum*, *Phalaris tuberosa*, Kentucky bluegrass (*Poa pratensis*), *Bromus unioloides*, Sudan grass and millet are also used on the irrigation areas, the last two generally as grazing catch crops for dairy cattle.

Strains of pasture species

The concept of strains within pasture species has become an important feature of pasture improvement in Australia, particularly within the winter rainfall region.

The most notable example is that of subterranean clover (*T. subterraneum* L.) of which a large number of naturally occurring strains, differing mainly in the time they take to mature, have been found and isolated. This clover has the usual virtues of a pasture legume. In addition, it produces heavy crops of highly nutritious and edible seed—its four-seeded burr being readily

eaten by all classes of stock. The heavy seed yield combined with partial burial of the seed provides ample margin for regeneration, even under adverse conditions. The value of the dry seed stage as a source of stock food increases in proportion as the length of growing season diminishes, and in the early maturing varieties the seed stage is more important than the growing stage. In general, where they are able to mature, the later strains produce the greater yield so that, for any one locality, the latest strain which will satisfactorily complete its life cycle before the onset of hot, dry summer conditions is used. In districts with long growing seasons or under irrigation, a late maturing strain such as Tallarook is successful, whereas under the short growing season of the lower rainfall areas an early maturing strain of the Dwalganup type must be sown. In the intermediate zone, mid-season strains such as Mt. Barker and Bacchus Marsh are used.

The Australian strain of lucerne (*Medicago sativa* L.) typified by the Hunter River variety, is superior under local conditions. Within it a number of local strains have appeared, and perhaps the most important of these is the " Dryland " lucerne of Victoria used in low rainfall wheatlands.

New Zealand certified perennial ryegrass (*Lolium perenne* L.) has been shown to persist better than other introduced strains. Certain local Victorian strains, however, persist equally well, and under some conditions are earlier and more active in winter.

Similarly in cocksfoot (*Dactylis glomerata* L.) the Victorian strains harvested in parts of Gippsland and the Western District are earlier than the New Zealand certified strains, which, however, are superior to other imported strains.

In *Phalaris tuberosa* only one strain, apart from the ordinary commercial seed, is commercially available. It is a broad-leaved, late-maturing type known as the Burbank strain. Strains have been bred by both the Waite Institute and the New South Wales Department of Agriculture, but these have not yet appeared on the commercial market.

The New Zealand certified perennial white clover (*Trifolium repens* L.) is the most common strain of this species sown, but a vigorous, high-producing strain, known as the Victorian Irrigation White Clover, has been developed in the irrigation areas of that State. Both are superior to the " wild " strains.

A Victorian strain of strawberry clover (*Trifolium fragiferum* L.) grows more freely and flowers earlier than the New Zealand strain, while the large-leaved, robust " Palestine " strain of this species is a valuable addition to the range of pasture plants.

In general, different strains of the tropical and subtropical pasture species have not been commercialized, with the exception of Guinea grass (*Panicum maximum* Jacq.) in which, of the three strains described, a fine-stemmed strain known as " Green Panic " grass is gaining popularity.

Strain differences do exist in Rhodes grass, especially between local and introduced material, but their use is still in the experimental stage.

State Departments of Agriculture have well-organized seed certification schemes assuring trueness to type, purity and germination of several of the more important grassland species and strains. These include the four main strains of subterranean clover, three strains of perennial ryegrass, Wimmera ryegrass, *Phalaris tuberosa,* cocksfoot and white clover.

Seeds Mixtures and Planting Rates

The Australian pasture mixtures are essentially simple, rarely including more than four or five species, even in favoured pasture areas. This simplicity is due, in part, to the relative paucity of grassland species suitable to any given locality and purpose ; partly to the rapid domination of the sward by two or three species of any complex mixture, consequent upon the rapid annihilation of the weaker species during periods of drought (which occur in all localities to some degree) ; and partly because strains of known reliability and performance are available for the majority of the pasture species—at least those of the southern belt.

Grass-legume mixtures

The principle of the grass-legume mixture is thoroughly appreciated and is applied wherever practicable. However, no pasture legumes are available for tropical conditions, and lucerne is the only legume for subtropical conditions away from the limited white clover areas of the coast. By comparison, the southern half of the continent is well supplied with sown pasture legume species. Where rainfall conditions are assured, white clover (*Trifolium repens*), late and mid-season strains of *T. subterraneum*, red clover (*T. pratense*), strawberry clover (*T. fragiferum*) and, to a lesser extent, alsike clover (*T. hybridum*) and lucerne (*Medicago sativa*) are sown in suitable combinations with grasses such as perennial ryegrass (*Lolium perenne*), Wimmera ryegrass (*L. rigidum*), Italian ryegrass (*L. italicum*), cocksfoot (*Dactylis glomerata*), *Phalaris tuberosa* and some others of lesser importance.

Under lower rainfall conditions, early and mid-season strains of *T. subterraneum*, lucerne and *Medicago tribuloides* are sown with grass species such as Wimmera ryegrass (*L. rigidum*) and *Phalaris tuberosa*.

Monospecific plantings

Monospecific plantings are common, and occur primarily in that phase when newly cleared land is being colonized. In Queensland, where suitable legumes are not available for use on the extensive areas of Rhodes grass swards established on the brigalow and softwood scrublands, nor for sowing with the tropical Para, molasses and Guinea grasses planted on the rain forest scrubs of the north Queensland coast, these grasses are most frequently planted alone.

In many instances, *Paspalum dilatatum* has also been sown alone on the primary clearing burns of New South Wales and southern Queensland, but mixtures with Rhodes grass and also white clover were more commonly sown and generally advocated.

Monospecific sowings of lucerne are commonly made for hay under favourable conditions and also to establish thin stands for grazing in areas of lesser rainfall.

The other very common monospecific sowing is of *Trifolium subterraneum* on the initial clearing of forest and woodland, on the low fertility podsols of western Victoria and the lateritic soils of South Australia and south-west Western Australia. On these soils, gramineous species are extremely difficult to establish until fertility has been materially improved by several years of legume growth.

In a slightly different category is the introduction of *T. subterraneum* into the natural *Danthonia*/*Stipa* grassland of the southern savannah woodlands by surface cultivation. Here, a single species, in this case a legume, is introduced into an existing sward of native grass species which is left undisturbed so far as is possible. Blue lupin in Western Australia is another example of monospecific planting.

Seed rates and some typical mixtures

A low rate of seeding is characteristic of pasture establishment in Australia. In part, this is due to the high establishment rate obtained in warm, fallowed soils, but in the drier sown pasture areas water relationships are the controlling factor and relatively few plants per unit area are able to persist. Low fertility and costs are factors in the case of new clearings. Simple mixtures frequently do not exceed 5 lb. per acre and monospecific plantings may be as low as 1 to 2 lb. On fertile soils receiving high rainfall, the more complex mixtures may sometimes be sown at the rate of 30 to 35 lb. per acre; but such high rates are probably unnecessary and tend to reflect old and imported European practice. It is not possible to give examples of all mixtures sown in Australia, but some typical mixtures are listed below (all rates quoted in lb. per acre) :—

Winter pasture mixtures (perennial pastures)

(a) *long growing season.*

(1)	Perennial ryegrass	5 to 10
	Cocksfoot	3 „ 10
	White clover	1 „ 2
	Subterranean clover (mid-season or late)	2 „ 3

On heavy soils the proportion of perennial ryegrass and white clover may be increased, but on light soils the proportion of cocksfoot and subterranean clover may be increased. One or more other species may be added to the above perennial pasture mixture to increase early growth or for special conditions, as for example :—

	Red clover	2 to 5
	Italian ryegrass	2 „ 5
	Alsike clover	1 „ 2
	Strawberry clover	quarter
	Lucerne	2 „ 3
	Paspalum	2 „ 3
(2)	*Phalaris tuberosa*	3
	White clover	2
	±lucerne	2

(b) *medium growing season.*

(3)	Perennial ryegrass	5 to 10
	Subterranean clover (mid-season)	2 „ 4
	±lucerne	2 „ 3
(4)	*Phalaris tuberosa*	2 „ 4
	Subterranean clover (mid-season)	2 „ 4
	±lucerne	1 „ 3

Aggressive species are not sown with *Phalaris*.

(c) *short growing season.*

(5) Subterranean clover (mid-season or early)	2 to 4
±Wimmera ryegrass	2 „ 4
±cover crop of winter cereal	Half normal planting

Winter pasture mixtures (temporary)

(6) Red clover	2 to 5
Italian ryegrass	3 „ 6

Summer pasture mixtures

(a) *subtropical pasture.*

(7) Sown on burn—	
Paspalum dilatatum	5 to 10
White clover	1 „ 2
±lucerne	2 „ 5
±Rhodes grass	2 „ 4
(8) Sown on renovated pasture—	
Red clover	4
Italian ryegrass	6
±white clover	1 to 2
±perennial ryegrass	5
(9) Sown on ploughed land—	
Kikuyu	(from cuttings)
±white clover	1 to 2
±Subterranean clover	2 „ 4

(b) *sub-coastal pasture.*

(10) Rhodes grass	4 to 12
±lucerne	1 „ 3

(c) *tropical coast.*

(11) Molasses grass	2
Para grass	3
Guinea grass	2
or each species sown separately.	

(d) *summer grazing.*

(12) Sudan grass	10 to 12
(13) Japanese or white millet	8 „ 10

Irrigated pastures

Modifications of above mixtures are used and two comprehensive mixtures recommended by the Victorian and New South Wales Departments of Agriculture are :—

	(14) *Victoria*	(15) *N.S.W.*
Perennial ryegrass	10	12
Cocksfoot	5	2
White clover	1	2
Red clover	2	2
Lucerne	...	1
Subterranean clover	1	...
Alsike clover	1	...
Strawberry clover	¼	...
Prairie grass	2	...
Italian ryegrass	5	...

Above mixtures may be modified, and reduced to simplest form, become :—

(16) Perennial ryegrass	12
White clover	2

In New South Wales subterranean clover at the rate of 2 to 4 lb. per acre is frequently added to irrigation mixtures. Other mixtures used under irrigation are 2, 5, 6, 7, 12 and 13 above or modifications of these.

Methods of Sowing

Planting procedure

The actual method of sowing and the machinery used depends to a large extent on the form of associated farming and land utilization. Thus in the dairying districts relatively small acreages are sown at one time and this is done by the usual small farm machinery. In the wheat areas the large scale machinery of that industry, both tractor and horse-drawn, has been adapted to, and is widely used in, pasture establishment. The wool and cattle stations, even in good rainfall areas, are not usually equipped with cultivation implements ; also, in some of the pastoral areas, the topography makes cropping undesirable or impracticable, in spite of a satisfactory rainfall. The absence of the necessary machinery for cultivation in many cases may prevent pasture improvement on as intensive a scale as climatic conditions might otherwise permit. In such cases, sowing on extensive areas of natural pasture is often done by contract.

In all the higher rainfall areas pasture seed is sown on the surface and is only lightly covered. In intensive farming districts sowings may be made by hand, with or without a hand broadcasting machine, or a small fertilizer drill may be used. If the latter, the seed is mixed with fertilizer or some other diluent such as dry soil, fine dry farmyard manure, etc. Grain drills fitted with special plates, and grain and fertilizer drills fitted with a special grass seed box attachment are commonly used. A grass seed box attachment is sometimes fitted also to a direct drop type of fertilizer distributor. In sowing with a drill the feed tubes may be lifted from the shoes so that the seed is scattered on the surface, or alternatively, the drill is set to sow at the shallowest depth that the clutch will engage, so that the seed is barely covered. Covering of the seed is done with a light harrow run over the ground after sowing, or drawn behind the drill. Harrows improvized from brush or metal chain, or a tine harrow turned upside down, are most satisfactory, and occasionally a ribbed roller is used if the ground is suitable. If the seed is to be sown with a cover crop, a common practice is to sow the cover crop first with half the fertilizer and to plant the pasture seed later with the remainder, either immediately or when the cover crop is just brairding.

On black soils which contract and crack on drying, pasture seed is also planted at a depth of three-quarters to one inch to keep the seed in contact with the moist layers, and in drier districts seed is sown deeply, up to one inch deep, frequently on dry soil. The large scale cereal machinery is used and the seed is sown either alone or mixed with fertilizer, according to whether or not a pasture seed box is fitted to the machine. A "combine" so fitted permits

fertilizer and cover crop to be sown at the normal depth and the pasture seed on the surface. Following harrows cover the pasture seed.

When pasture seeds are introduced into natural pastures the wheat combine * is the implement most commonly used as it permits cultivation, fertilizing and sowing to be done in the one operation. Thus large areas can be planted relatively cheaply.

Irrigated pastures are frequently sown in dry soil or on land previously irrigated and reworked in anticipation of autumn rains. Most successful establishment is obtained in this way. Failing rains one or more following irrigations may be necessary, and great skill is required to prevent water-logging, soil caking and malting of the seed. Some irrigated soils offer difficulties to successful pasture establishment and require further investigation.

Time of planting

Autumn is the usual planting time for winter-growing species, but the actual date varies according to the rainfall characteristics of the district, and may range from February to June. In cold districts, early autumn plantings are necessary so that the pasture may be sufficiently well established before cold weather. Spring sowings are hazardous, particularly in the medium growing season areas, and are never attempted in the short-season areas. However, in areas of assured rainfall, they are sometimes preferred, particularly if summer species such as *Paspalum* or lucerne are included in the mixture. They have further advantages in that clovers and lucerne partially escape attacks from lucerne flea (*Smynthurus viridis*), pea mite (*Halotydeus destructor*) and slugs, and in that winter weeds are more controllable.

In the summer rainfall areas the winter and spring periods are too dry for planting and the summer growing species can be safely planted only from early summer to early autumn. Late plantings are avoided in areas subject to frost or where the winters are particularly dry.

Fertilizers

Fertilizers are rarely used in the northern pasture region. This is due primarily to three important facts :—

(1) nitrogen appears to be a most important limiting factor, and top-dressings of nitrogenous fertilizers cannot be economically applied to extensive areas ;

(2) sowing of pastures is almost entirely confined to the better soils, where on new land, or fallow, sufficient nitrogen is available, to permit establishment and good growth for several years ;

(3) sown pasture legumes, which might respond to other manures, are not available.

In the southern region of sown winter-growing species, ample leguminous components are available and, with minor exceptions, responses to phosphates

* The cereal drills and combines may be either of the disc or tine shoe type. The disc type is used on cereal stubbles where a certain amount of surface " brash " is present, whilst the tine implements are better for surface seeding on natural pasture. Both types are of the stump-jump variety.

are obtained over almost the entire region. On many of the less fertile soils the satisfactory establishment and maintenance of clover swards depend upon their use. The fertilizer most commonly used is superphosphate, which is applied with the seed, and also subsequently as annual or biennial top-dressings. The rate of application varies with the climate and soil. In the higher rainfall areas an application of 2 cwt. per acre is usual, and under irrigation the optimal level is frequently 4 cwt. per acre or even more. With decreasing rainfall, the rate of application decreases, and in the driest areas where pastures are sown, rates as low as half a cwt. per acre are used.

Certain red, acid, volcanic soils along the eastern scarp and in Victoria are able to "fix" soluble phosphates. Both lime and superphosphate are often applied to these soils, but probably the most satisfactory use of phosphatic manures is their application to an established sward.

Although acid soils are widespread in southern Australia, the use of lime is rather limited. This is explained partly by the fact that the most commonly sown pasture legume, *T. subterraneum*, is tolerant to moderately acid soils, and partly because available lime is reasonably satisfactory. Where lime is used, applications range from 5 cwt. to one ton per acre, but heavy dressings are rarely, if ever, applied. Lime is applied to the fallow several weeks or months prior to planting.

Responses to potash have been obtained on some Victorian soils in Gippsland and the Western District, particularly following excessive cropping, hay cutting, or the continued use of superphosphate (Twentyman, 1933). Small applications of potassic fertilizers not exceeding one cwt. per acre are necessary and result in a re-invigorated clover sward.

The application of nitrogenous fertilizers to pastures is rarely an economic practice, but on parts of the north coast of New South Wales applications are made to increase the winter and spring growth of temporary pastures of red clover and Italian ryegrass. Half a cwt. of sulphate of ammonia per acre is applied at seeding and a further half cwt. may be broadcast on the young pasture during late winter or spring if the pasture is not growing rapidly.

Other mineral deficiencies

A number of mineral deficiencies have been demonstrated in certain Australian soils, mainly where pasture legumes have failed to make satisfactory growth.

The occurrence of "coasty" disease, due to cobalt-copper deficiency, and the failure to establish sown pastures over large areas of coastal sandy soils in Western Australia and South Australia, led to the investigations of possible mineral deficiencies in the soils.

On the soils of the south-west coastal districts of Western Australia establishment of sown pastures is made possible by small application of $CuSO_4$ at the maximum rates of 2·5 lb. or 5 to 10 lb. per acre, according to soil type (Teakle and others, 1941).

On the sandy calcareous soils of South Australia where pasture establishment is difficult, copper sulphate at higher rates of application (20 lb.) has given variable results (Riceman and others, 1940), and as a result of recent work excellent establishment has been obtained following the addition of zinc

sulphate, at the rate of 28 lb. per acre, to the superphosphate-copper sulphate mixture.

Certain ironstone soils of South Australia which have given poor responses to the application of superphosphate have recently been shown to be deficient in molybdenum (Anderson, 1942), and there is evidence to suggest that molybdenum deficiency also occurs in parts of New South Wales (Shaw and Barrie) and Tasmania (Stephens and Oertel, 1943). The results of this work have not yet been applied to pasture establishment.

Some of the red basaltic soils of the central coast of New South Wales are deficient in magnesium and here the use of dolomite has overcome the difficulty.

Early Management

The management of the pastures in the year of establishment differs widely with (1) the kind of pasture, (2) the type of farm husbandry, varying particularly with the stage of development from the pioneering stage to more established agriculture, and (3) the use to which the pasture is to be put. We have the one extreme in the case of Rhodes grass planted on newly cleared brigalow scrub, where stock may be withheld during the actual growing period for up to three growing seasons, with the twin objects of allowing the grass sward to increase in density and to provide a medium to carry fire so that the standing timber and dry logs may be cleared. A light grazing is given during the late autumn and winter, the burning being done in August or September. The other extreme is typified by the spring-sown permanent pastures on irrigation or fertile valley lands, where grazing is commenced at the earliest possible opportunity and generally 8 to 12 weeks after planting.

Early management of pioneer pastures

Poor seed-beds are the rule, whether the pastures are sown on the burn or some form of cultivation is first attempted. Competition, both from the original understorey and the suckering tree species, is general to a greater or lesser degree, except in the rare instances where forest is cleared by grubbing.

To afford sown species every opportunity of establishment, stock is generally withheld during the first year of growth, except that flocks of sheep or herds of cattle may be turned in for short periods, or even driven systematically across the new clearings, to effect consolidation. With the annuals, *e.g.* subterranean clover and Wimmera ryegrass, the main object is to ensure ample seed production, and in exceptional cases of unusually robust establishment this is promoted by judicious intermittent grazing, especially where the Wimmera ryegrass is too vigorous and tends to dominate the legume.

Great skill is required in dealing with regrowth of the original forest or scrub flora. The eucalypts vary widely in their capacity for regrowth, but the authors know of no case in which root suckering occurs in this genus. The acacias (wattles) are more difficult, many species root-suckering freely, *e.g.* brigalow (*Acacia harpophylla*) in Queensland. The burn also stimulates the germination of the seed of many of the eucalypts, acacias and other genera, and seedlings thus provide an additional hazard. Finally, there remains the wide range of understorey shrubs and other miscellaneous plants, many of which

are stimulated to extreme activity either by the fire or the throwing back of the ecological succession to the primary phase. Mismanagement of a pioneer pasture in the first year or two can lead to a condition of regrowth which it is quite uneconomic to remove until some 10 to 12 years later.

Tree regrowth is almost invariably dealt with by slashing the suckers which, of course, arise from below the ringbarking. They are generally allowed to make appreciable growth so that root reserves are drawn upon, and the slashing is not a lopping, but a wrenching of the sucker, thus minimizing the number of potential points of regrowth. When skilfully timed, it is rarely necessary to slash more than twice. The operation is done toward the end of the growing season—in southern areas in early autumn, in northern areas in early winter. Tree seedlings not uncommonly attain heights of 6 to 8 feet in the first growing season, especially in the summer rainfall areas, and these are cut back. (Poisoning of the suckers and seedlings is also practised to a lesser extent.) When dried, the regrowth, together with the dried pasture, provides enough fuel for a second or third clearing fire in which much of the standing and fallen timber is also consumed. The use of second and third burns is more general in the summer rainfall areas than in the winter rainfall areas, though in the southern rain forests of Gippsland repeated burning is necessary.

Where regrowth is light, a combination of grazing and slashing suffices to deal with it, especially where low scrub is originally cleared by ploughing.

In the clearing of the southern rain forests, Scotch thistle, bracken fern and blackberry are extremely difficult to deal with in the regrowth phase. The thistle usually remains dominant in only the first and possibly the second year. The method is to cut wherever possible in order that the pasture sward may receive as much light as possible.

Where bracken fern is to be anticipated, the planting of Kikuyu grass (*Pennisetum clandestinum*) provides the only alternative to a laborious and frequently losing battle to cope with the fern. Kikuyu grass does compete successfully. The stolons overtop the bracken and in their search for the grass shoots cattle trample and seriously damage the bracken. Kikuyu is successful on the coast of New South Wales and has been used also in south-east Victoria and south-east South Australia, where sufficient summer rain permits vigorous growth of the grass.

The control of blackberry is equally difficult and laborious, but here again Kikuyu grass is often of great help in providing a straggling growth of edible herbage above the canopy, while rapidly and densely colonizing the ground surface.

On the lateritic soils of South Australia and Western Australia and on certain poor soils of coastal New South Wales, Victoria and Queensland, a *Xanthorrhœa* species, " Blackboy," is a characteristic component of the native flora. It is extremely resistant to fire, especially in the younger stages. It is dealt with very simply by punching a crowbar vertically down the central pith and pouring a cupful of power kerosene into the hole.

Cover crops are rarely used in the pioneer phase and only when a reasonable seed-bed can be attained. This is possible in the case of the treeless scrubs of the lateritic " sandplain " areas in Western Australia and the rather similar low

scrubs in South Australia. A light seeding (20 to 30 lb. per acre) of oats or wheat is used with subterranean clover, or subterranean clover and Wimmera ryegrass. The cover crop may be grazed during the winter, or alternatively stripped for grain—hay cutting is generally impracticable. The objectives of the cover crop are twofold : (1) to provide the pasture seedlings with protection from cold winds and to minimize sandblasting effects, and (2) to provide immediate cash returns either in the form of grazing or grain. In good seasons excellent results are obtained, but in dry years both crop and pasture may fail and re-seeding may have to be adopted.

Early management of sowings on natural pastures

The main example here is the sowing of subterranean clover, with or without perennial and Wimmera ryegrasses, on surface-cultivated natural pastures. Grazing of the sown areas must proceed normally, otherwise the native and naturalized species still present will compete too strongly during the seedling stage of the sown species. Stock are not removed from the paddocks even during the operation of seeding, but they are generally withdrawn in late spring for 6 to 8 weeks to allow the sown species to seed as freely as possible. Lenient grazing is practised throughout the following summer when the ripe seed is lying on the ground.

Early management of sowings on primary cultivations

This is the commonest case of the use of cover crops in Australia, more particularly in the winter rainfall areas, though their use is by no means universal. For instance, when *Phalaris tuberosa* is the main perennial grass component of a mixture, the use of a cover crop is dangerous and is rarely attempted. Though more commonly used in the medium rainfall areas, cover crops are occasionally also used in the lower rainfall areas. The cover crop is usually oats or wheat, sown at half to three-quarters the normal rates, and whenever possible it is harvested for cereal hay, thus removing the crop before soil moisture is entirely exhausted in the spring. Care is taken to ensure that the cereal stand does not become too dense, and in good seasons grazing is practised in early spring to prevent excessive growth.

Early management of pastures sown in crop rotations

The early management of good clean pastures sown on fallowed or clean land in regions of good rainfall is relatively simple. After 8 to 12 weeks from planting, when the pasture may be 6 to 9 inches in height, a rapid grazing is given with a rather high concentration of stock. The object is lightly and evenly to reduce the leafage of the most vigorous species in the pasture in order to encourage the slower growing or more prostrate species, and also to encourage tillering. A second grazing of this type may be given and thereafter the pasture is grazed intermittently at intervals of 3 to 5 weeks, or as circumstances dictate. In general, perennial pastures are not allowed to go to hay in the first year.

In pastures where thistles or other upright weeds develop, they are cut with a mower or scythe following the initial grazing, or earlier if necessary.

The application of nitrogen in winter or spring to pastures of coastal New South Wales has been referred to in the section dealing with fertilizers.

Early management of irrigation pastures

This closely follows early management of the pastures of the better rainfall areas. Stock, of course, have to be removed during irrigations, and great care has to be exercised to avoid "pugging" of the young swards, especially on dairy farms where heavy stock only are available. Initial grazings are given only when the land is dry. This is not difficult because the irrigation areas are mainly in low rainfall districts.

Summary

Agriculture in Australia is rigidly confined by climatic factors to a small proportion of the continent, and within that portion pasture is still largely in the pioneer stage; in consequence, pasture improvement is concerned with the colonization of newly cleared land, or primary cultivations, or the establishment of sown species in natural pasture, to a greater extent than it is with establishing temporary or permanent pastures in defined crop rotations.

Pastures are established in areas with an annual rainfall as low as 15 inches and as high as 150 inches, and under conditions ranging from dry winters and wet summers to dry summers and wet winters.

The number of species used is relatively small. The main species in the winter rainfall areas are :—perennial, Wimmera and Italian ryegrasses (*Lolium perenne*, *L. rigidum* and *L. italicum*), cocksfoot (*Dactylis glomerata*), and *Phalaris tuberosa*, and white, subterranean, red, alsike and strawberry clovers (*Trifolium repens*, *T. subterraneum*, *T. pratense*, *T. hybridum* and *T. fragiferum*), lucerne (*Medicago sativa*) and the annuals, *Medicago tribuloides*, *M. lupulina* and *M. denticulata*. In the summer rainfall region, the main species are *Paspalum dilatatum*, Rhodes grass (*Chloris gayana*), Para grass (*Brachiaria mutica*), molasses grass (*Melinis minutiflora*) and Guinea grass (*Panicum maximum*), lucerne (*M. sativa*) and, to a lesser extent, white clover (*T. repens*).

Many of these species are widely used in their countries of origin but some, particularly subterranean clover, Wimmera ryegrass and *Phalaris tuberosa*, have an importance in Australia not attained elsewhere.

A common requirement in most Australian sown pasture species is vigorous seedling establishment to enable the species to succeed under poor seed-bed conditions, which are general in all but the cereal and intensively cultivated lands, and in competition with existing native grassland species or regenerating species of forest and scrub.

Pasture mixtures are essentially simple. The principle of the grass-legume mixture is fully appreciated and is applied wherever possible. Monospecific plantings are common, and in the summer rainfall areas, where satisfactory pasture legumes are not available, the perennial pioneer grass species such as Rhodes, Para, Guinea and molasses grasses are almost always sown alone. In the south, subterranean clover is frequently sown alone on natural pastures or primary cultivations. Lucerne occurs as monospecific plantings sown

densely for hay under better conditions, or sparsely for grazing under low rainfall conditions.

A low rate of seeding is characteristic, but plantings range from one lb. per acre in low rainfall areas to 30 or 35 lb. per acre in high rainfall areas.

The method of sowing the seed varies and includes hand broadcasting, the use of small farm machinery (grain and fertilizer drills), and, finally, the adaptation of large-scale wheat machinery. Although cover crops are frequently used in very cold areas, on wind-eroded soils, on primary cultivations and in the cereal areas, their use is not universal, and in dry districts is definitely detrimental to pasture establishment.

The use of superphosphate at seeding is general, with minor exceptions, throughout the winter rainfall region. Lime, potash and nitrogen for special purposes are used to a lesser extent. Mineral deficiencies occur. In the summer rainfall region, the use of fertilizers on pasture is rare.

The early management of pastures sown on cultivated cropped land is straightforward and involves mainly careful grazing and the occasional use of the mower to control weeds. In pioneer pastures, early management is mainly concerned with the control of regenerating tree or understorey species and is a process requiring considerable skill and experience with the particular species concerned.

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Climate as influencing Role of Grassland

Full dependence on grassland for the successful consummation of a high production agricultural programme is an experience unique among agricultural countries of the world, and New Zealand, particularly the North Island, can claim this position almost unchallenged by any other country. It is not that our soils are more fertile or that our farmers are more intelligent: it is merely a matter of a climate favourable for high-production grassland. Our winters are mild, the summers are not excessively hot and the rainfall is copious and fairly uniformly spread. These facts are intimately linked with our farming fortunes.

In New Zealand all stock are for the most part wintered outdoors, the only protection necessary against the elements being rugs for the higher-producing and winter-milking dairy cows. Some herds are fed indoors on hay and roots plus a little concentrate, largely as a protective measure against poaching of pastures rather than of necessity on account of the cold.

The agriculture of the North Island is in many respects unlike that of the South Island, due primarily to climate. Practically speaking, the North Island has an all-grass farming system, while the South Island has short- or long-rotation pastures freely interspersed with arable crops—wheat, oats, barley, root and forage crops, or as an alternative to this arable and cropping programme, permanent grass (mainly montane tussock) of low production capacity.

A climatic analysis of the two Islands is given in Table 1.

Table 1

Meteorological Data showing General Climatic Analysis and the Differences in Climate between the North Island and the South Island of New Zealand

	North Island	*South Island*
Annual mean temperatures in ° F.		
earth at 1 foot deep	58	55
minimum earth	44	37
maximum earth	72	69
air	56	51
minimum air	27	21
maximum air	83	86
Mean daily grass minimum temperatures (° F.)	41	35
Mean annual minimum of grass minimum temperatures (° F.)	20	13
Ground frosts occur on (nights)	56	118
Snow falls on (days)	3 (high country only)	6
Bright sunshine		
duration (hrs.)	1654 to 2416	1584 to 2510
mean hours	2110	1935
Wind		
mean 24-hourly anemometer run (miles)	127	97
mean annual highest 24-hourly run (miles)	426	368
Rainfall		
mean annual (inches)	48	33
falls recorded on (days)	160	130

Range of annual rainfall (inches)	*North Island*	*South Island*
both Islands	30 to 150	15 to 250
South Island. East of mountains	...	15 „ 35
South Island. West of mountains	...	80 „ 250
Rainfall (inches)		
mean annual South Island. East of mountains . .	...	28
mean annual South Island. West of mountains . .	...	152

Original Vegetative Cover and Kinds of Grasslands

Primitive New Zealand for the most part consisted of three major plant formations: (1) forest, varying from the semi-xerophytic southern-beech forests to mesophytic rain forest; (2) fern, heath and scrub with developmental phases to forest; and (3) tussock grassland with steppe characteristics.

The southern-beech country is for the most part mountainous and has on the whole responded poorly to conversion to surface-sown permanent grassland. Some 11,000,000 acres of mixed rain-forest, mainly in the North Island, and for the most part too hilly to plough, have been felled and surface-sown to grass. Treatment of some 7,000,000 acres has been relatively successful, but 4,000,000 acres are still tending to revert to fern and scrub. A relatively small area of very steep country has been abandoned as it has reverted to fern, scrub and initial forest phases towards the ultimate climax of primary forest once more.

Some 6,000,000 acres of easy sloping or flat country of the deforested area have been stumped, ploughed and sown to long rotation and permanent grass, and there have been added to this several million acres of pumice, sand and kauri gum-land country that originally carried fern, heath, scrub and young forests in varying stages of development. These deforested, de-scrubbed and ploughed areas furnish most of our butterfat, fat lamb and fat beef; the hill country is essentially for sheep breeding and production of wool and store cattle, although it competes with much ploughable land in the production of fat lamb and fat beef wherever top-dressing with artificial fertilizers and good grazing management are applied. The copious rainfall and the equable, temperate climate play an enormous part in this development.

East of the mountain ranges of the South Island the rainfall is too low for high-producing permanent grassland, and it is here that cereal production, arable crops and temporary and short rotation pastures characterize the farming. In the higher rainfall areas of the South Island, however, short-rotation grasslands merge into long-rotation grassland with some high-producing permanent grassland on the exceptionally favoured localities.

The establishment and early management of pastures on these major soil types is the theme of this contribution.

Montane Tussock Grassland

In the South Island natural tussock grass is the dominant vegetation of the unploughable hill country east of the mountain range. Before the introduction of the plough vast areas of flat land in the South Island also carried tussock. On the wetter west coast the dominant vegetation was forest, and for the most part still is.

The natural tussock grasslands occupy some 14,000,000 acres, the main plants being *Poa* tussock, *Festuca* tussock and *Danthonia* tussock. The

tussocks are interspersed with shrubs, and of these the wild Irishman * is a characteristic feature. Between the tussocks and shrubs that characterize the vegetation of the mountainous country are lesser grasses and herbs that provide much of the grazing.

These tussock grasslands are essentially low in carrying capacity—one merino sheep per acre at best, down to one sheep for every 5 acres. They can be grazed safely by sheep for some 9 months of the year. For the remaining 3 winter months the sheep are removed to lower levels or on to relatively safe sunny slopes. " Snow raking " is common during the severe snowstorms that sometimes fall in winter on the normally safe winter grazing country.

The management of these runs is in large blocks with fences few and far between, excepting in certain blocks where efforts have been made to wire net to exclude rabbits. Burning is practised to control the shade of the tussock and to eliminate any tendency for succession to shrub to take place. This tendency becomes particularly apparent as the rainfall increases and as the forest line is approached towards the west and in sheltered gullies and less exposed portions of the country. Actually vast areas of tussock are potential forest land, and trees when planted do very well over most of the lowlands and up to approximately 3000 feet.

Burning is done for the most part in the early spring or when there is sufficient dryness to carry a fire and yet sufficient moisture in the base of the tussocks to exclude the possibility of burning too low into the crown of the plant. This periodic opening up of the cover to the full light of day permits greater numbers of herbs and finer grasses to thrive between the tussocks and the young growth of the tussocks themselves that comes away after the fire provides a certain amount of grazing.

The maintenance of this ecological balance of tussock—herb and finer grasses—is the keynote to successful farming of montane tussock grassland ; where recognition of this balance has been the basis of grazing management, little or no deterioration of the vegetative cover is evident. On the other hand, where excessive burning has been combined with overstocking with sheep and the infiltration of the rabbit in thousands on to these low grazed areas, very marked deterioration has set in. The tussock has completely disappeared and vast areas have reverted to a lower vegetative plane dominated by mat-forming plants such as scab-weed interspersed with hardy annual grasses and weeds of the deep-rooting rosette type such as catsear and stork's bill, or to plants with underground creeping stems such as sorrel. In some moister parts, *Poa pratensis* and browntop form low-producing semi-closed swards of low production. Regeneration of the tussock cover in these overgrazed and overburned areas is a problem of the future grazing management of this country, and complete resting from burning and from sheep and rabbit grazing is necessary before much regeneration of the original sward can be expected. On this high country of low rainfall, the ecological balance between virtual desert and a montane tussock cover is extremely delicate, and it has been the past lack of appreciation of this sensitivity of balance that has led to the widespread destruction evident to-day. As we move to areas of slightly higher

* See key to common names, p. 207.

rainfall the balance in favour of tussock is more stable until the scrub-forest line is met, and here the succession, if not properly managed, passes slowly to useless scrub or stunted xerophytic forest dominated ultimately by southern-beech.

Deforested Hill Country

The useful timber trees are for the most part removed for milling, or where it is uneconomical to remove the timber the larger trees 2 feet in diameter or over are left standing. All the remaining trees, scrub, tree fern, lianes, etc., are cut during the winter and early spring and left until the summer to dry. The bush burn takes place in midsummer, and many anxious hours precede the actual decision to burn, as upon this operation the success or failure of the grassing largely depends.

In the higher rainfall areas—from 60 to 100 inches annual rainfall—the periods of really dry weather are short and there are rarely more than one or two favourable occasions suitable for burning in any one season. Should such opportunities be missed, fresh undergrowth of fern arises in the subsequent autumn and winter, and a clearing so left may never be burnt over, reverting rapidly to secondary scrub and ultimately to young forest without providing any grazing. Where one has the power to crush with cattle, the fern and scrub may be controlled and with much logging up and secondary fires the country can ultimately be grassed.

Given a good sweeping burn, however, all but the stumps and larger logs are consumed and the area presents a black and white feature dominated in a good burn by white ash—what is called a white burn—and in a poor burn by black ash—called a black burn. The white burn consumes almost everything —including masses of leaf mould and practically all forest seeds and fern spores. The black burn leaves much leaf mould, forest seeds and fern spores. On this differentiation between a " white " and " black " burn often depends success or failure of the grassing operations. In both cases the grass seed is sown by hand ; the seed is carried on to the burn by pack horses, and the bags distributed about the burn at intervals convenient to the sowers.

The seeds mixtures vary somewhat according to the nature of the country, but for the most part species covering a wide ecological range are included so as to cover the complex mosaic of soil types and aspects, sunny, shady, steep or sloping, that present themselves in any one hill country sowing. Allowance must also be made for a wide range in soil fertility, and for the most part for a general decline of fertility once the ash and humus of the burn have been depleted.

The following seeds mixture is typical for primary forest burns (lb. per acre) :—

Italian ryegrass	4
Perennial ryegrass	15
Cocksfoot	6
Crested dogstail	3
Poa pratensis	1
Browntop	1
Danthonia pilosa	3
White clover	2
Lotus major	1
Total	36

The seeds mixture for the secondary fern and scrub burn takes into account the harder seed-bed conditions and the general lower soil fertility as compared with the primary burns.

A typical mixture for high rainfall areas is as follows (lb. per acre) :—

Perennial ryegrass	10
Crested dogstail	4
Browntop	2
Lotus major	1
Danthonia pilosa	3
White clover	1
Total	21

For the lower rainfall areas :—

Perennial ryegrass (or good ryegrass seconds 20 lb.)	10
Crested dogstail	4
Browntop	1
Danthonia pilosa	3
Subterranean clover	3
White clover or mixture of suckling clover, clustered clover and striated clover	1
Total	22

In the development of hill country grasslands, climate plays a large part in deciding just how easy it is to swing the ecological balance in favour of grass rather than in favour of secondary growths—bracken fern, hard fern, water fern, manuka and other scrubby growth that precede the re-establishment of the forest trees. In the west coast of both islands the rainfall is high (80 inches and over), and very great difficulties have been experienced in successfully grassing much of the steeper hill country owing to the difficulties of securing hot, penetrating burns to clear off the secondary scrub and fern growth. As the annual rainfall declines, the conversion to grass becomes easier, but shrubby growth such as manuka, kanuka, cottonwood, tauhinu, etc., still remain a problem wherever the sward is open as a result of dry and infertile soil conditions. Periodic cutting of these and the development of *Danthonia* swards has won many millions of acres to grassland on the drier areas of the east coast. In the intermediate rainfall areas sward-forming grasses such as browntop, associated with *Danthonia*, crested dogstail, cocksfoot, *Poa pratensis*, Yorkshire fog, sweet vernal, ryegrass, white clover and annual clovers have successfully grassed vast areas. In all these operations stock, and particularly cattle, play an important part, and must in many districts be regarded as mere implements in the handling of hill country. Fundamental to the process of sward formation on hill country is the ecological factor of light and shade, the burning, crushing with cattle and man-handling with the slash-hook all having as their primary objective the reduction of shade above the developing turf. Certain pasture species such as browntop, *Lotus major* and paspalum can tolerate fairly dense shade and will persist for some time in moderately tall secondary growth, making good recovery after the secondary growth has been burnt off. This principle of introducing

shade-tolerating species on to hill country likely to revert to secondary growth has been the basis of much successful work in controlling secondary growth throughout the higher rainfall areas of both Islands.

Fencing to control cattle and to rest the country periodically plays a large part in the development of hill country. Close and continuous grazing encourages several troublesome forms of secondary growth—hard fern and piripiri may be cited on the higher rainfall areas and manuka on the dry. These plants and many others require the full light of day, either to spread laterally or to establish from shed seed. Close and continuous grazing provides this ecological condition of full light to the ground surface, whereas periodic rests shade the soil surface and thus tend to inhibit vegetative spread and seedling establishment.

Topdressing with artificial fertilizers wherever applicable has played a large part in the successful grassing of much hill country; the two factors mainly responsible are (1) increased stock-carrying capacity with consequent greater crushing power; (2) better swarding of grasses and clovers and less bare ground for re-establishment of secondary growth from seed or by lateral spread.

Topdressing of hill country, particularly in the North Island, has enormous potentialities not only in staying the trend towards a sward of low-fertility-demanding grasses and clovers, but also in reversing that transition so that higher-fertility-demanding species such as ryegrass, cocksfoot, white clover, crested dogstail, etc., will once more take as important a share as was the case following the bush burn with its high virgin fertility. After the war, top-dressing from the air may be a means of greatly accelerating this process.

The conversion of typical rain-forest country to grassland in New Zealand has meant much to our national wealth, and these grasslands are the essential background of our overseas trade in fat lamb and prime beef. They afford excellent facilities and conditions for breeding animals of good frame and good constitution that respond remarkably well on the better pastures of the lowlands when brought there for fat lamb production or for prime beef. The establishment of pasture on certain areas of our hill country has been fraught with many a hardship and many a disappointment for our pioneer settlers. For the most part success has ultimately crowned their efforts, but in some cases the breaking in and maintenance costs have made demands greater than the individual settlers could bear, and these have ultimately been obliged to pack up and walk off, leaving the area to revert unobstructed to secondary growth and ultimately to forest. A new settler with more ready cash may then take over the derelict farm. With the re-erection of fences, burning and sowing, and with ample cattle the ecological swing once more turns to grass rather than forest, and the ultimate fate of the country will depend on just whether the newcomer can apply the energy, expenditure and knowledge necessary to win the battle. A keener appreciation of the difficulties and more timely assistance by the State would have saved many a wreck in the really great effort New Zealand pioneers have put into the development of our hill country grasslands.

Ploughable Country

Light lands of the South Island (Flay, 1933)

A short-rotation farming system characterizes the light ploughable country of the South Island, and pasture sowings are merely part and parcel of this system. Thus we find in practice many methods of establishing such pastures. They may be sown after oats or wheat in the autumn with rape or oats as a cover crop, or with rape, turnips, kale or green-feed oats, or with grain in the spring, or in the spring after a grazing of autumn-sown cereals. They may be sown with turnips in the summer or they may be sown alone in the autumn following a grain or other crop. The best results from a strictly pasture point of view are from sowing without a cover crop, but when one takes into consideration the farming practices on these light lands the combination of grass with crops possibly gives the greatest return per acre. That is but an appreciation of the fact that these soil types are not good grassland soil types and will remain down for only a few years at best. Therefore, during the period immediately following the cultivation and while growing conditions prevail, pasture plus crop give a yield far in excess of the pasture or crops alone. The practices of sowing down with oats or wheat or the oversowing of these cereals in the spring have many opponents in the agricultural advisory world, but the fact remains that the farmer is still adopting the double-barrel crop, if for no other reason than that there is less likelihood of missing his quarry where two barrels are loaded instead of one.

The cultivation practice preceding the sowing of these light lands often entails a great deal of labour, particularly where the land has been white-cropped for some years and has run to twitch grasses such as twitch, *Poa pratensis*, browntop, dryland browntop and creeping fog. Ploughing is usually done in early summer and frequent harrowing or grubbing is recommended; deep working just prior to sowing is avoided, as this tends to leave the surface too dry. Rolling two or three times prior to sowing is recommended.

If soil conditions at time of sowing are moist and there are good prospects of further rain, the seed is then broadcast, but if the soil conditions are dry and likely to remain so, drilling in 7-inch drills is adopted. The manure is drilled in with the seed in these latter cases, but is broadcast in the former, 1 cwt. per acre of superphosphate being used.

Relative to other parts of New Zealand this manurial dressing is light, but it is consistent with the experience of light lands in general where the rainfall is low, 1 to 1·5 cwt. per acre being the maximum amount of phosphate that the pasture can profitably utilize in any one growing season.

The seeds mixtures for light lands are also on the light side and are relatively simple. The following are typical (lb. per acre) :—

Italian ryegrass	6
Perennial ryegrass	20
Cocksfoot	6
Montgomery red clover	4
White clover	1
Total	37

or

Italian ryegrass	6
Perennial ryegrass	10
Cocksfoot	15
Montgomery red clover	4
White clover	1
Total	36

Subterranean clover at 2 lb. per acre may be added to either of the above mixtures.

Temporary 2-year pastures are widely used on these light lands. The following mixture is typical :—

Italian ryegrass	30
Broad red clover	6
Total	36

Seed production is profitable and popular and in normal years excellent seed crops are produced. In such cases a mixed pasture is sown, but where the seed crop is perennial ryegrass, Italian ryegrass is omitted in the mixture, and the rate for the perennial ryegrass is correspondingly increased. This prospect of a seed crop will often dominate the seeds mixture sown, and at times the efficiency of the sowing as a grazing pasture sward is reduced. Thus Italian ryegrass, short-rotation ryegrass and perennial ryegrass may not be blended where seed production is likely, nor may Montgomery red clover and broad red clover be used in combination ; this somewhat curtails the possibilities of pasture improvement from a grazing point of view.

The sowing down of these pastures is spread over a wide period from September to March, and the time of sowing conforms generally to the optimal time of sowing for the fodder or cash crop sown in association with it. These crops again predetermine the grazing management in the first six months of the pasture sward.

The after-grazing-treatment tends to be light rather than intensive and close grazing is avoided, particularly in dry weather when persistency of the sward is at stake. Annual topdressings of from 1 cwt. to 1·5 cwt. superphosphate are applied together with dressings of carbonate of lime at 5 cwt. per acre every few years.

The pasture phase in these light lands of the South Island is of very great importance in the farming economy of these soils. It is the pasture phase that ensures the running of animals and the consequent build-up of soil fertility from their residues. The legume phase also contributes nitrogen and the root mass maintains soil structure. The extensive use of such pastures, interposed between harvested and cash crops, in large measure determines the continued successful farming of these light lands.

Light soils of both Islands under a copious rainfall of 40 *to* 60 *inches*

Such soils include pumice, littoral sands, stony river and sandy silt deposits.

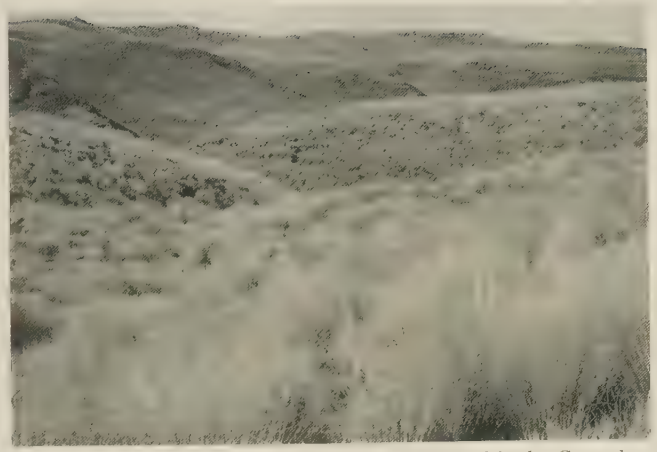

FIG. 27.—Montane tussock country at 2500 ft. altitude, Central volcanic plateau, North Island.

FIG. 28.—Typical montane tussock country, South Island.

FIG. 29. Typical foot-hill country, the lower reaches of which are ploughable and readily converted to high production grassland.

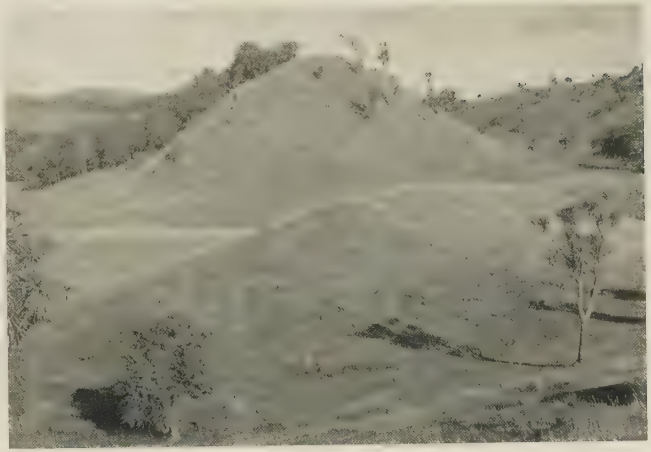

FIG. 30.—Typical North Island hill country of the Taihape district. The cabbage tree (*Cordyline*) is a characteristic feature.

Fig. 31.—Deforested hill country in process of conversion to grass.

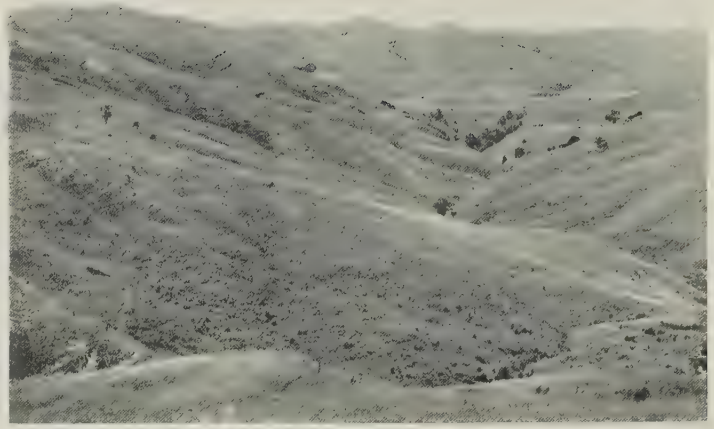

Fig. 32.—Typical North Island hill country (Wairarapa) admirably suited to cattle and ewe breeding. With some top-dressing this country turns off fat beef and fat lambs.

Fig. 33.—Light lands of the South Island under moderately low rainfall. Typical cereal and short-rotation grassland country.

Fig. 34.—Pasture phase in short-rotation country of Canterbury, S.I.

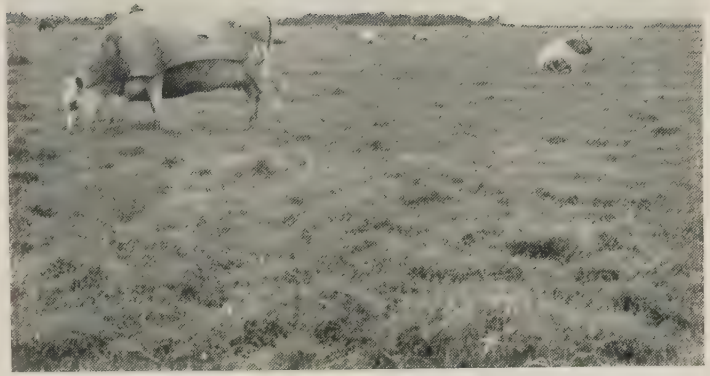

FIG. 35.—Dairying scene in mid-winter in New Zealand. Rugs afford the only protection necessary from cold and wet.

FIG. 36.—The root crop phase in regrassing heavy, clay soils.

FIG. 37. Early winter (May). Hay and silage are the main supplementary feeds, both of which are fed out on the pasture to stock.

FIG. 38. Pasture rested for *in situ* winter and early spring grazing. Such pasture reduces greatly the quota of silage, hay or roots for winter keep.

Fig. 39.—Development of heavy, wet clays by ploughing. Dairying on young long-rotation grassland.

Fig. 40.—High-production dairy farm on developed pumice land, Waikato.

Fig. 41.—Fat lamb production, under rotation grazing, on long-rotation grassland on the heavy, rather wet soil type of the North Island.

Fig. 42.—Young developing pasture showing effect of stock nitrogen.

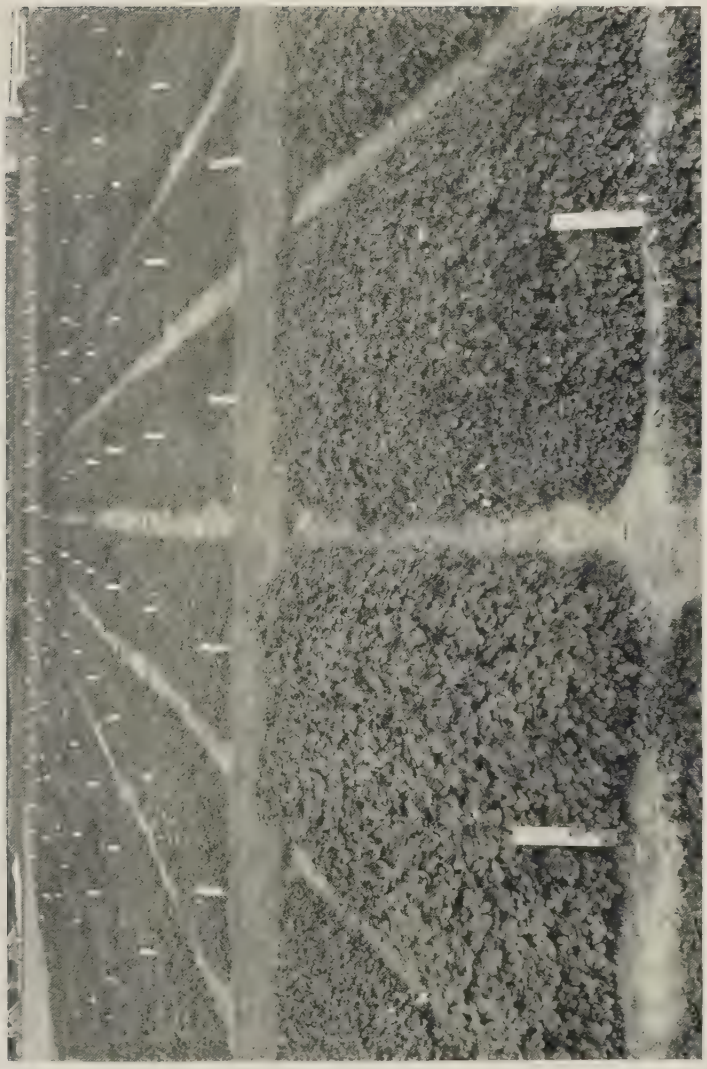

Fig. 43.—Plot testing for type in commercial lines of white clover. The ground test, coupled with the laboratory tests for certain species, set and maintain the standard for New Zealand certified seeds.

In the grassing of all these soil types, clovers play the leading role for the first few years of establishment, and where the climate is mild, as in the North Island, very high-producing long-rotation to permanent grasslands have been established on soils that initially were of very low fertility, carrying a meagre growth of stunted shrub and fern. Several million acres of pumice soil in the central portion of the North Island are typical of such light soils. The development of these soils from areas that would scarcely feed a rabbit per acre to those now carrying high-producing dairy farms is one of New Zealand's most picturesque grassland romances, rivalling in ecological interest the conversion of our once-forested hill country to grassland.

A mild climate, high rainfall, good clovers and phosphate, and the animal, with its treading and manurial residues—these are the main actors in this grassland drama. In the development of these lands, the scrub is first cut and burnt, and if the stumps are small the area is ploughed 5 to 6 inches deep; it remains in the furrow to weather for 4 to 5 months, after which the area is rolled with a Cambridge roller. The surface is then disced, harrowed and again well consolidated by rolling. This consolidation is essential for good clover establishment. The seed is sown broadcast with distributor on the rolled surface and covered with a chain harrow. Superphosphate at a rate of 3 cwt. per acre is broadcast with distributor at the time of seeding. In the higher rainfall areas and milder climate of the North Island full utilization may be secured of the higher phosphate dressings as compared with the South Island, where 1 to 1·5 cwt. per acre appears to be the maximum amount that can be exploited. This exploitation of phosphate to grow clovers—white clover, red clover, subterranean clover or other annual clovers—is the first phase. The abundant clover growth carries the stock and the stock by their treading and manurial residues return humus, nitrogen, phosphate, potash and lime in amounts sufficient to meet the requirements of the grasses of the sward; when this condition is attained, clovers and grasses blend together to form the balanced pasture for the dairy cow or breeding ewe. Cattle are necessary to deal with the initial clovery phase, more particularly the red clover phase, in the first year of development.

The initial dressing of 3 cwt. of phosphate per acre is not enough to carry forward the initial development; a further 3 cwt. is applied 4 months after sowing and a further 3 cwt. 6 months later. The sward, after these initial 9 cwt. of superphosphate in the first 12 months, carries sufficient stock and puts the land in such heart that the normal 3 to 4 cwt. per acre dressings will be found to be sufficient to continue the development. Without the initial good start, however, these light lands may break the heart of the most ardent settler, who may spend what little money he has and yet fall far from his goal of establishing profitable grassland. The whole question depends on how many stock per acre one can carry and feed adequately, for in the end it is the stock that make the country. The phosphate initiates the cycle and maintains the clover, but the grass element—particularly ryegrass—is dependent on the treading, pruning and manure of the stock. This principle applies to the whole of our grasslands.

The early grazing management of these light lands is as follows:—Stock are put on as soon as there is sufficient feed to graze. This early stocking, with

consequent consolidation and manurial residues, is important and too often the initial grazing is left too late. Light cattle or sheep are preferable to heavy cattle or dairy cows for the first grazing, but once the clover growth, and particularly the red clover, comes away strong, heavy cattle or dairy cows are introduced. Fairly close subdivision is essential in order to obtain full utilization of the clover and to ensure even treading and even redistribution of the animal residues. Heavy, periodic grazings with frequent shifts are much to be preferred to small stock numbers over a long interval of grazing. Where dairy cows are used for grazing it is preferable to mow the red clover and to wilt it prior to grazing. A sufficient area is mown each mowing for one day's grazing. Wilting tends to make the red clover more palatable and reduces the likelihood of bloat.

An aspect of dairy management in the developmental phases of these light lands, where the feed is predominantly clover, is the prevention of unduly high feed flavours in the milk and cream. Recent research carried out within the area of these light pumice soils showed conclusively that clover was mainly responsible for the flavour and that those farms that were on the lower rungs of the ladder, as far as pasture improvement was concerned, were the worst offenders. Here the predominant clovers were suckling clover or subterranean clover, with some paddocks running more white clover and red clover. However, once the farms developed through the clover phase and the pastures became grassy, the feed flavour problem was greatly reduced.

Costs of developing these light lands vary considerably, but the figures compiled by Smallfield (1933) give a very good idea of the cost of developing large blocks of pumice country.

The mean cost of pasture establishment for farms (£8. 5s. 0d. per acre) is made up of the following items :—clearing 30s., cultivation 40s., grass seed 38s., fertilizers 57s. per acre.

Heavy clays, clay-loams, kauri-gum lands, etc.

These for the most part have a rolling to undulating topography and constitute many million acres of our ploughable soils. They are heavy textured soils, inclined to pack, and, unless well drained earlier by mole or tiles, are wet in the winter and hard set in the summer.

For the most part, short and long-rotation pastures, interposed by crops for 1 or 2 years, characterize these soil types. Pasture establishment on these is relatively simple on account of the general high rainfall and fair initial soil fertility that enable grasses and clovers to become established sufficiently well to give moderately high pasture production from the outset. Certain of the poor soils within this group, however, are extremely infertile and heavy applications of fertilizers and lime are necessary to raise the pasture production up to a point where animals may be carried in sufficient numbers to play their part in the development to grass. The kauri gum lands of North Auckland may be cited in this connexion.

The general procedure is to plough after the tussock or scrub has been cleared or after the stumps of the forest trees have rotted and have been removed. After a 4 to 6 months' fallow, the land is double disced, harrowed and rolled and may either be sown direct to pasture or go into root, cereal

TABLE 2

Summary of Costs of developing Twelve Dairy Farms, Ngakuru Blocks, Rotorua District

Items	Costs for Twelve Farms												Totals	Cost per acre
Area grassed (acres)	(1) 114	(2) 147	(3) 126	(4) 93	(5) 153	(6) 122	(7) 126	(8) 133	(9) 111	(10) 113	(11) 119	(12) 130	1487	
	£	£	£	£	£	£	£	£	£	£	£	£	£	£ s. d.
Buildings	613	353	364	375	625	395	736	410	442	444	421	412	5,590	3 15 2
Drainage	...	...	...	...	...	...	7	4	4	4	4	6	29	0 0 5
Fencing	631	519	452	498	375	372	330	345	359	378	269	339	4,867	3 5 6
Shelter	44	27	37	26	19	27	33	19	15	23	17	33	320	0 4 4
Tracks	...	3	...	...	...	9	...	3	5	5	10	2	37	0 0 6
Water-supply	218	155	176	247	187	132	100	122	132	118	178	134	1,899	1 5 6
Pastures	952	1356	820	791	1274	1190	848	1064	999	1017	952	1040	12,313	8 5 7
General overhead	361	314	305	237	315	265	200	203	197	202	178	202	2,979	2 0 1
Totals	2819	2727	2154	2174	2795	2390	2254	2170	2153	2191	2029	2168	28,034	18 17 1

or fodder crop. Two such crops may be taken, after which the land is prepared for grass, which in the North Island is generally sown in the autumn. In the South Island sowing is mainly done in the spring. The pastures may be sown alone or they may be sown with a cover crop—either green oats, oats for chaff, or rape or turnips. Here again the same arguments arise as to whether the grass should be sown with or without the cover crops; again it is a question whether the slightly better establishment of the pasture without the cover crop pays for the undoubted advantages of the early and bounteous feed possible from a good cover crop. Generally speaking, we find the better the conditions for pasture growth soon after sowing, the less inclination is there to adopt cover crops, and conversely, where pasture establishment is slow cover crops are more common. Thus, as on the light lands it becomes a question of the economic necessity of obtaining a high bulk of feed soon after sowing to recompense for the time the land has been idle, and the cost of ploughing, seeding, etc.

Whether with or without a cover crop, the pasture development proceeds towards a ryegrass/white clover/crested dogstail/cocksfoot dominant type of pasture; whether these remain as such or degenerate towards a lower grade pasture dominated by browntop, Yorkshire fog, sweet vernal, rushes and other weeds depends primarily on the maintenance and building up of soil fertility. Drainage, either by mole or tile, is also important. The same story regarding development through stock in sufficient numbers applies to these heavy lands just as to the light lands. Where the stock-carrying capacity can be raised and maintained round about six to eight ewes, plus cattle, per acre all the year round, or to approximately three-quarters to one dairy cow per acre, then one is assured of a soil fertility standard that will keep ryegrass dominant in the sward. Top-dressing with 3 cwt. phosphate and 1 ton of lime per acre every 5 years is necessary to keep the clovers growing well to provide their quota of feed for the grazing animals. This clover phase on the poor class of soils is just as essential as in the case of light pumice soils, and many a heart-breaking experience would have been avoided in the past had the original settlers had the necessary finance to provide the all-essential phosphate and lime for the initial breaking-in operations on many of these soil types.

In purchasing seeds, also, the unfinancial settler looks for cheap seeds, and perhaps nothing has contributed more to the difficulties of pasture establishment than the use of poor commercial strains of herbage seeds. Without good persistent strains of clover the lime-phosphate dressing loses much of its value, and without good persistent strains of ryegrass, particularly, much of the value of the residues of the grazing animal is lost. Good high-producing clovers exploit the phosphates and lime and good high-producing strains of grasses fully utilize the waste residues of the animal; without these good strains the development to permanent high-producing grass is just impossible on the soil types so far dealt with.

Seed certification applied to the best herbage types, whether as natural ecotypes or derived from bred materials from these good ecotypes, has done more to ensure successful pasture establishment on marginal and semi-marginal land than any other factor that could be mentioned. Not that certification alone ensures success, but it ensures that the factor of soil fertility, whether

derived from the bag, or from the animal, or from virgin soils, can operate in in full measure.

The seeds mixtures sown on these heavy soils are dominated usually by perennial ryegrass and white clover. The following is typical (lb. per acre) :—

Italian ryegrass	6
Perennial ryegrass	30
White clover	3
Montgomery red clover	3
Total	42

Cocksfoot, crested dogstail and timothy may be added and the perennial ryegrass correspondingly reduced.

A recent development in New Zealand in an effort to improve these dominant ryegrass/white clover pastures has been along the lines of hybridization of persistent Italian ryegrass and leafy perennial ryegrass to create a hybrid that carries with it some considerable persistence of the perennial and the undoubtedly higher palatability and better winter-growing propensities of the Italian. Persistent strains of Montgomery red clover are also proving useful, particularly in the South Island, for improving the summer production from these pastures. Thus, for the future, one may envisage a mixture somewhat as follows (lb. per acre) :—

Short or long-rotation ryegrass hybrid	20
Certified perennial ryegrass	20
Certified Montgomery red clover	4
Certified white clover	2
Total	46

Improvement in cocksfoot and timothy may create useful contributing species, but these at the moment, even if added to the above mixture, will not contribute much under a full utilization and intensive grazing plan such as the ryegrass-dominant pastures demand.

In the North Island, particularly, both light and heavy soils that are turned up to give grassland along the lines indicated above tend rather to become very long-rotation grassland or truly permanent grassland. In the South Island the development is from short-rotation (3 to 4 years) to long-rotation (6 to 9 years) or even to permanent grassland. This development towards longer rotation or to permanent grassland can, on the soil types in question, be carried too far. There is a tendency for these heavy soils, even under the best of farm management, to become compacted to the exclusion of aeration and to hold the water unduly in the winter. This tends to eliminate the ryegrass/white clover element and to encourage browntop, Yorkshire fog, rushes, pennyroyal and similar weeds. The periodic break-up, say every 8 to 10 years, reconditions the soil and ameliorates the conditions for the high-class grasses and clovers. The break-up also offers a golden opportunity for new and better strains of grasses and clovers to be introduced. Normally, one or two root fodder or grain crops will be taken after the break-up, but there is

no reason why grass should not follow grass if the root, forage or grain crops are not required.

Fertile, alluvial plains

These constitute the best grassland soils in New Zealand; there are no difficulties attendant upon pasture establishment nor is there the need to build soil fertility through the clovers and stock before the grasses of the sward can come away. The danger is rather that the grasses, particularly ryegrass, come away so fast from seed that they smother the slower-establishing clover. Sufficient numbers of stock may be run right from the outset on these soils to supply sufficient nitrogen, phosphate, potash and lime to keep the grasses and clovers up to a high pitch of production. Top-dressing with additional phosphate and lime appears to give little or no response, the effect, if any, of such top-dressings being quite completely masked by the shower of fertility dropped by the stock. On these soils also one has great latitude in the seeds mixture sown. The simple perennial ryegrass/white clover sward is highly popular, and a mixture such as the following is regularly sown (lb. per acre) :—

Perennial ryegrass	40
White clover	3
Total	43

or

Italian ryegrass	6
Perennial ryegrass	34
White clover	3
Total	43

The dairy farmer prefers somewhat more complicated mixtures as his somewhat more lax type of management gives greater scope for cocksfoot and timothy to thrive.

The following seed mixture then is typical :—

Italian ryegrass	5
Perennial ryegrass	25
Cocksfoot	8
Timothy	3
Red clover	3
White clover	2
Total	46

As in the case of the dominant ryegrass/white clovers on heavy soils, it is felt that the short-rotation ryegrass type will enter freely into the grasslands and will be more or less perennial on these highly fertile soils.

Strains in Pasture Plants—their Evolution and Application

The significance of strain in pasture plants is rapidly becoming recognized throughout the world, and it is not too much to prophesy that gradually the

pasture-seed trade of the world will come to be based on pedigree and type. Man in his agriculture throughout the world has taken up the wild species at a certain point in their evolution, and has applied them in a variety of ways. New habitats have been created, and just as species have been evolved in response to the call of the habitat under wild conditions, so to-day we can recognize strains in species that have arisen under cultivation. The more widely and variously used the species, the greater the significance that can be attached to strain within those species.

Perennial ryegrass, cocksfoot, white clover, and red clover, for example, are widely exploited in grasslands in virtually all parts of the world. Each district and each country, according to soil and climate, have used these species in roughly four different ways: (1) for long-rotation truly permanent pasture; (2) for short-rotation pastures that are ploughed every 2 to 4 years; (3) for strictly temporary pastures that last only 1 to 2 years; and (4) for seed production purposes under any one of these categories.

From our research up to the present, one may say that different strains of herbage plants have developed according to the farming system practised. The old permanent pastures with certain exceptions carry the permanent strain. The short-rotation areas have evolved a short-lived type; the arable and annual cropping areas have run distinctly to an annual type. Crops grown specifically for seed have evolved towards stemmy, high seed-yielding types. Countries with cold winters have produced winter-dormant forms. Countries with long, dry summers have produced forms with scanty herbage, stemmy, quick-maturing and short-lived, and those with mild winters have produced winter-growing forms. The permanently grassed, high-production soil types have high-production forms, and the low-production, permanently grassed soils low-production types.

Specific examples of type evolution may be quoted. Within the high-production, permanent pasture areas of Hawkes Bay and Poverty Bay, 60 to 80-year-old pastures are not uncommon. Within these there have evolved a true perennial ryegrass and a high-producing, highly persistent white clover. A similar white clover has been located in the old perennial pastures of the Rangiora district in Canterbury. Throughout Akaroa, on roadsides and older established fields, the New Zealand cocksfoot type has been evolved—not unlike certain of the denser and more leafy hay-pasture types of Great Britain. Great Britain itself has produced definite old pasture herbage types—Kentish wild white clover, British indigenous perennial ryegrass, indigenous cocksfoot and timothy. The irrigated country of Northern Italy produces a distinct ecotype of white clover—the Ladino type—large-leaved, wide-spreading and highly productive forms. Similarly, in Australia, a somewhat distinct large-leaved type has evolved under irrigation there. Montgomery red clover is a product of the comparatively old pasture of Montgomeryshire in Wales. Climate specifically sets its seal on type—the cold countries of the world produce winter-dormant strains, late to start growth in the spring and early to cease growth in the autumn, and so inbred is this cold-induced, winter-dormant characteristic that even under much less severe climates the behaviour is the same. Thus, Danish cocksfoot and strains of red clover from Canada, Russia, Sweden, Austria and Germany are winter-dormant in New Zealand, probably

for as long as they are in the country of origin. Montgomery red clover from Wales is intermediate in winter dormancy between the strains of Canada, Russia, etc., and the ordinary broad red strains of New Zealand. Montgomery red clover in New Zealand is as distinct from broad red clover when grown here as it is in England, and this applies irrespective of the soil conditions under which it is grown. Montgomery red clover, however, grown for say 30 years under a mild climate and under high productive and therefore highly competitive associations in New Zealand, may develop into a uniformly higher producing, less winter-dormant type than its prototype in Montgomeryshire.

Years of arable farming and of short-rotation farming systems have left their mark on strain, just as years of permanent grass-farming have left their mark, only in the first case annual types have been evolved, and the more arable the farming practice adopted the more truly annual the type. Thus arable Europe has produced the Dutch white clover—an annual even under the best soils and climate we have in New Zealand. Short-rotation systems of farming have evolved short-lived types of perennial ryegrass, the broad red clover and the short-lived types of white clover. In Australia, Wimmera ryegrass is replacing in certain districts the somewhat later-maturing and longer-lived Italian ryegrass, and drought areas there have evolved their own peculiar types to harmonize with the short production periods between those of intense drought. Wimmera ryegrass, drooping clover and quick-maturing forms of subterranean clover such as Dwalganup may be regarded as types specially evolved by the drought habitats of Australia.

The important point to bear in mind is that these inbred characteristics do not readily change. A false perennial short-lived ryegrass type or a Dutch white clover fails to persist even when sown under the best of permanent pasture conditions, whereas on the other hand truly perennial types carry with them high persistency wherever sown, just so long as they are kept reasonably within the same climatic zones.

Any serious attempt to classify pasture strains and to produce seed of these on a commercial scale calls in the end stages for an organization that will see to the production and distribution of those proven types that are the outcome of natural selection or intensive breeding. This becomes obviously important when it is recognized that, whereas seeds of species may be readily detected by eye or by microscopic examination, seeds of strains are impossible to identify by eye, and certification of type by actual paddock inspection and sealing becomes essential.

The following species and strains are now being produced under Government certification in New Zealand—Pedigree, m/s (mother seed) and p.p. (permanent pasture) perennial ryegrass ; pedigree, m/s and p.p. white clover ; pedigree, m/s and ordinary certified Italian ryegrass ; certified cocksfoot ; certified browntop ; certified pedigree, m/s and ordinary Montgomery red clover ; certified pedigree, m/s and ordinary broad red clover ; certified pedigree, m/s and ordinary short-rotation ryegrass. Multiplication of the last-named on a commercial scale has just commenced.

In any plough-up and resow programme too much emphasis cannot be laid on the use of these certified seeds. Perhaps nothing in the past has had such an adverse effect on ploughing, cropping and pasture renewal as these poor

mongrel strains of pasture seeds. In the North Island, particularly, there arose a strong top-dress-back school, as against the plough-up and resow school, largely as a result of experience after the use of mongrel, low-persistent hybrid strains that had been evolved under a short-rotation farming system in the South Island. Certified seeds have been the antidote to the anti-plough school.

General Considerations regarding Laying Down, Establishment and After-Treatment of Pastures

Time of sowing

In the North Island the best time to sow pastures is in the autumn, preferably some time in March after the break in the weather following the summer. Such pastures are generally sown alone, the only cover crop or temporary element used being Italian ryegrass. Spring sowings may be made towards the end of September or early October, and these also are generally sown without a cover crop other than Italian ryegrass or possibly green oats. Sowings later in the spring and early summer are also made, and generally coincide with the best time to establish cover crops such as rape, turnips, Japanese millet, etc.

In the South Island, particularly in the far south, spring sowing is general and the pastures are generally sown with a cover crop—oats or wheat for grain, rape, turnips, blue lupin, green oats, etc. Coming north into Canterbury, early autumn sowings are popular and the month of February is the best for these. The autumn sowings are generally without a cover crop and many sowings for seed production are made at this time.

Preparing the seed-bed

The seed-bed for all pasture sowings should be firm, and this is particularly important with regard to the clovers. Many failures in the establishment of the clovers can be attributed to an insufficient consolidation of the seed-bed; failure to establish clover may have a far-reaching effect on the subsequent development of the sward. Other than on the most fertile of soils, clover is the key to pasture development, and too much stress cannot be laid on the importance of selecting the best strains of clover and of proper preparation of the seed-bed to ensure their successful establishment. In the preparation of the seed-bed some thought and work should be given to the levelling out of the surface to avoid small irregularities, crests, hollows, break-outs and finishes, particularly where mole draining is to follow the laying down. Further, crests dry out over-rapidly and much production is lost. Hollows become water-logged and frequently run to weeds or low-producing coarse grasses. A uniformity of land surface goes a long way towards a uniformity of pasture sward and aids greatly towards a uniform utilization by the grazing animal. Any fills through levelling must be well consolidated by rolling before sowing the seed.

The period of pasture establishment is critical and much depends on an early production that will enable an early stocking, preferably by light animals in large numbers. Much damage is often done to the developing sward by not stocking early enough. On fertile country growth of the early-producing species such as Italian and perennial ryegrass may smother the clovers and the

slower establishing grasses, unless pruned back by grazing. On less fertile country pasture swards can develop only through the animal. For the most part, it can be said that New Zealand pastures are stock-made and no sward can ever develop into high-production grassland until a high stocking concentration can be built up. Where we have virgin high soil fertility sufficient feed is rapidly produced to carry early the requisite number of stock to build the sward and to maintain it at a high production level. Such swards are usually grass-dominant right from the start. With poor soils such as pumice, gum lands, heavy rolling clays or clay loams, sands, etc., some help must be given to the developing sward at the time of establishment to produce growth, and the key here is clover liberally fed with phosphate and lime.

After-treatment: Building soil fertility

Once the country has been built up to a carrying capacity of six to eight ewes per acre plus cattle, or from two-thirds to one dairy cow per acre, top-dressing with phosphate may be reduced, but it is unwise to relax annual top-dressing until this carrying capacity is reached. From my experience here, it takes the residue—dung and urine—from six to eight ewes per acre or approximately one dairy cow per acre to grow ryegrass or any other high-producing grass to perfection.

Measurements made here on a research basis go to show that animals, full-grown wethers, grazing a high production pasture—up to 15,000 lb. dry matter per annum—return to the soil in their dung and urine nitrogen equivalent to that contained in approximately 15 cwt. of sulphate of ammonia, phosphate equivalent to that in 5·5 cwt. of superphosphate, potash equivalent to that in 10 cwt. 30 per cent potash salts, and lime equivalent to that in 2·5 cwt. carbonate of lime. It is this wealth of animal fertilizer and not the mere few hundredweights per acre of phosphate applied out of the bag—important as this may be to initiate the cycle and to keep the clover going strong—that makes for a high-producing pasture. Moreover, our research to date has failed entirely to formulate an artificial fertilizer to compare favourably with that dropped by the animal.

It will be obvious that in order to exploit this shower of fertility from the animal, grazing management must loom very large and full control of the grazing animal is imperative. Much has been said of the small paddock and the almost unbelievable carrying capacity of these under rotational grazing. It is my firm belief that the explanation of the undoubtedly high carrying capacity of the small well-controlled paddocks is due to the full utilization of all feed produced on the area plus a uniform redistribution of the animal residues over the entire pasture sward. Wide-range, uncontrolled grazing leads to poor utilization and frequently to the setting up of camps on sunny slopes, knolls or under the shade of trees. Control of the animal to ensure a satisfactory spread under grazing is therefore important. More fences, closed gates, avoidance of camps, paddock grazing for pigs instead of the bare pens reeking foul with valuable animal nitrogen, and closer attention to the night paddock in relation to the day paddocks, together with collection and spread on the farm of animal droppings that accumulate about milking sheds, sheep sheds and yards, are some of the points in the conscious planning that is

necessary to get the utmost from the valuable fertilizer manufactured and distributed by the animal on the farm. In my recent trip abroad, perhaps nothing impressed me more than the part the animal played in the building-up and maintenance of soil fertility in Great Britain and Europe generally. There, with the long period of indoor stall-feeding necessitated by the severity of the winter, the process of manure-making by the animal is more obvious than in New Zealand, but nevertheless we who have been associated closely with grassland development in New Zealand cannot fail to be convinced of the very great part the animal itself has played and is playing here in grassland development. It can be said that, apart from comparatively small areas of originally highly fertile soils, all of our worthwhile grasslands are stock-made, and it is becoming axiomatic in grassland farming that the more stock one can adequately carry per acre, the better and more highly productive do our grasslands become. The qualification " adequately fed " is important. Stock in large numbers inadequately fed over a long period of time tend to ruin the country.

Pasture management

In any ecological treatment of species it is clear that grasses and clovers vary according to their demand of light and shade. Thus, the ideal grazing management for one set of species will vary from that of another set. On country that can be raised in soil fertility to the ryegrass/white clover standard and where a grazing management is imposed to suit these two important species—not too close nor yet too lax—very few species can compete with them in the sward. Thus ryegrass and white clover become truly dominant, even despite the fact that cocksfoot and other species may be included in the mixture sown. A lax grazing management of that sward or repeated cutting for hay or silage will tend sooner or later to a cocksfoot-dominant sward, the ryegrass and white clover being subjugated by the shade thrown by the taller-growing and shade-enduring cocksfoot. Timothy, meadow foxtail, prairie grass, Yorkshire fog, red clover and *Lotus major* are similarly shade-endurers and actually demand shade before they can dominate in a pasture. Ryegrass and white clover require about equal light intensity and a grazing management that permits light to reach the crown of the ryegrass plant sufficient to induce tillering and to the creeping overground stem of white clover to induce spread, is an essential condition if this sward is to maintain dominance. Any system of grazing that leads to the exclusion of light well into the sward signals the exit of ryegrass/white clover as co-dominants of the sward. Recent work in white clover strains has produced a long-petioled white clover that is able to withstand very much greater competition than the ordinary strain, but this is due to the ability of the new strain to elongate its petiole or leaf stalk, and to dispose its leaf well into the light. So greatly has this characteristic been developed that the ryegrass/white clover ecological balance has to some extent been upset, and unless care in grazing management is exercised, the large-leaved, long-petioled white clover may smother the ryegrass associated with it. A recent trial here with varying the light intensities to the crown of rye-grass will illustrate the sensitivity of tiller-bud formation to light incidence.

Three lots of 150 ryegrass tillers were set out in boxes: one lot was placed

in the glasshouse for the duration of the trial; a second lot was placed in the glasshouse overnight and put out into the full light of day for approximately 4 hours a day; the third lot was in the full light of day for the duration. Tiller formation was as follows:—

(1) within the glasshouse for the whole period: 57 new tillers;
(2) in and out of glasshouse: 253 tillers;
(3) outside for the whole period: 605 tillers.

This shows that ryegrass-dominant swards need very specific grazing management to maintain them as such. Fortunately this style of management is one that envisages a full utilization by a grazing plan such as the more efficient graziers put into practice, that is, the ryegrass/white clover grazing management fits in perfectly with a full utilization, high-production permanent pasture plan. In this plan it would appear that grazing must not be lax nor yet too close, but a periodic clean-out of the bottom of the pasture is desirable. In a trial here over some 50 acres of 1 acre plots where the grazing management was consistently lenient, and where the mower had been used to top the taller growth that was neglected by the stock, *Poa trivialis* and *P. annua* developed so dense a bottom in the pasture as almost completely to inhibit tillering in the ryegrass and the spread of white clover. In the autumn following a wet summer, the botanical analyses showed up to 70 per cent *Poa trivialis* and *P. annua*. Following this invasion, a good clean-up with cattle and dry sheep in large numbers per acre quickly effected a marked improvement just as soon as this mat of bottom growth was cleaned out and light was once again let into the tillering crown of the ryegrass.

In rotational grazing where the spells between one grazing and another are not too long, almost ideal conditions are set up for the ryegrass/white clover sward to thrive. Where, however, the period between one grazing and another is excessive, great damage can be caused to the ryegrass, particularly where a pedigree white clover strain is used. In recent trials here, where an attempt was made to measure production under war-time conditions of reduced staff, and where too long a spell between one grazing and another had to be employed because of labour shortage, practically the whole of the ryegrass disappeared from the sward, pedigree white clover becoming dominant. The high-production ryegrass/white clover pastures were perfectly maintained while the staff was capable of measuring under some twenty-one grazings a year. When the number of grazings was reduced to twelve per year the damage recorded above was done.

A grazing management that suits cocksfoot does not suit ryegrass/white clover, and where a mixture of cocksfoot/white clover is desired a compromise between ryegrass/white clover and the more lax cocksfoot management must be introduced. Such a grazing management usually suits the dairy farmer. This more lax grazing system also suits paspalum, timothy and the red clovers. It also favours less desirable species such as Yorkshire fog and tall fescue.

In general, that system of pasture management which ensures full utilization by grazing while the herbage is in its most nutritive stage gives, year in and year out, the highest production per acre. By the most nutritive stage is not meant extremely short, luscious grass, but that which is not too young

nor yet too old. High production is not possible under a system of close and continuous grazing, nor yet is it possible under a lenient system where much of the feed produced is wasted. In the former it has been shown by experiment that the more often a pasture is grazed or cut the less it produces. It can be similarly shown that a pasture that is allowed to grow rank for most of the year also produces less than the efficiently grazed ones—there being a stage for each species or set of species between the close and continuous hard grazing and the over-lenient grazing, where not only is production greatest but also where the feed consumed is most thrift-giving. The system of grazing that best fits in with the above ideas is that of rotational grazing, and by rotational grazing I do not necessarily imply a large number of small paddocks with daily shifts. Actually the best dairy farmers to-day are adopting a rational system of rotational grazing where the whole herd is put to graze in one field for 2 to 3 days and is then shifted on to the next and so on round the farm. The main difficulties here are those fields far removed from the milking shed. Too often these are used only for day paddocks, and too often also the gates are left open so that the herd can wander back to the shed in the afternoon of their own volition. Then at night-time they are placed in a paddock convenient to the shed. The back paddocks will never become good pastures by this method of management for the simple reason that they are being drained of their soil fertility in so far as more is taken off them by the stock than is returned in their dung and urine. Roughly speaking, the dairy cow eats five meals per day—three meals in the daytime and two at night; very little is eaten after midnight, so that the cows go out to the back of the farm practically empty after the morning milking. In this way, the night or home paddocks benefit at the cost of the back paddocks and they may even become foul by an oversupply of animal droppings. By a stricter rotational system of grazing, the ideal management is coupled with an almost perfect redistribution of animal residues.

In rotational grazing with sheep, I feel that the strict day-shift, while leading undoubtedly to a high carrying capacity per acre, has rather put sheep men off the principle of rotational grazing on lines more rational to them than the strict day-shift system. In the Wairarapa, particularly, one could quote examples of such a rational, rotational grazing system being employed by several farmers on hill country, and their land stands out head and shoulders above that of the neighbouring farmers where close, continuous or a generally lenient system is practised over the whole farm. On most of the North Island hill country there is potentially a vast area that could maintain the better English grasses, but which are doomed to run at best to a dominant *Danthonia* sward under close and continuous grazing. The principle of resting such country, even for a whole growing season to permit the more shade-loving grasses such as cocksfoot, *Poa pratensis*, Yorkshire fog and browntop to develop, is sound. By grazing these spelled pastures with large mobs of cattle in the winter so as to clean them up by the spring, fertility is improved because of the greater bulk of feed to be eaten *in situ*; in the spring this is reflected by a greater growth of ryegrass and white clover in the sward, making ideal country for the ewe and its lamb.

Fixed grazing just prior to and after lambing is considered by most sheep

men to be the best for the stock. In this system cattle are added to control the excess growth in spring and to keep the stage of growth right for the sheep. Where the disparity of winter growth and spring growth is small, this system works well, but where the winter carrying is small an excessive loss is incurred by bringing insufficient cattle to eat the spring surplus. Special supplementary winter feeds will, of course, reduce this loss as more ewes can be wintered where these special crops are grown. Fundamental to all grazing management, however, is the principle of consuming the maximum of the cheap spring growth by the animal that pays best on the farm, or by conserving that feed for the self-same money-making animal by processing it as silage or hay. In this the dairy farmer is in a very much better position than the raiser of fat lambs, because dairy cows take more readily to hay and silage than do sheep. It is not economically possible to carry enough ewes over the winter and summer to control all spring growth by grazing, but the more winter and summer crops that can be grown, the more efficiently can the spring growth be utilized. Where the climate is suitable, seed production is an excellent way to help in levelling the carrying capacity so that less profitable utilization methods are avoided.

In all farming, dominantly grassland, the problem of stock feeding to ensure adequate rations throughout the seasons must dominate management, and often what is ideal for the pasture has to be sacrificed in order that the stock may be kept alive. Thus, very hard grazing in the summer is definitely harmful to the sward, but in a drought the farmer has no alternative. Similarly in the winter, poaching by the dairy herd may lead to greatly reduced yields, and to the intrusion of weeds such as buttercup, docks, Scotch thistle, pennyroyal, etc. In this latter regard, open-shed stall-feeding may yet find a place on the dairy farm in New Zealand. In the summer, irrigation could play a very much greater part in many dairying and fat lamb raising districts.

It is felt, however, that even at present we are far from fully exploiting the range of possibilities of levelling up the seasonal pasture fluctuations on the farm. Economic conditions largely dictate present practice, and the question of labour supply must be satisfactorily arranged.

The problem is that, roughly, on the high-producing dairy or fat lamb farm where there is nothing but grass, from 30 to 50 per cent of the farm has to be dealt with other than by grazing by the animals wintered on the farm. As mentioned before, the most popular methods to deal with this spring excess are extra cattle, hay and/or silage. The position in New Zealand (North Island) regarding seasonal spread of high production is shown in Table 3.

The real problem is how fully to exploit by the most efficient animal and with the minimum of loss the high pasture period between September and December. Recent research here into silage losses are rather disconcerting, the visible and invisible losses ranging from 30 to 50 per cent dry matter in silos or well-made stacks. By far the greater part of these losses is in an invisible form, the exact nature of which has not yet been determined.

Preliminary work on hay would also indicate that the invisible dry-matter losses are high.

The silage or hay period of growth averaged from four dairying pastures measured in 1943 accounted for some 4494 lb. per acre dry matter, which

represented 32·1 per cent total of dry matter from those fields for the year. A loss between 30 and 50 per cent of this dry matter is serious and should impress any country of the need for careful planning if the best use is to be made from the bulky, spring period of growth. The present tendency in New Zealand, as in most agricultural countries, is to dispense with labour-

TABLE 3

Seasonal Spread of Pasture Production from High-Class Sheep and Dairy Pastures

Pasture type and location	Dry matter per acre in lb. in 4-month periods				Percentage growth in 4-month periods		
	Sept. 1 to Dec. 31	Jan. 1 to April 30	May 1 to Aug. 31	Total	Sept. to Dec.	Jan. to April	May to Aug.
Dominant ryegrass/white clover under sheep, Marton . .	6133	3576	1650	11,359	54·0	31·5	14·5
Dominant ryegrass/white clover under sheep rotationally grazed, Massey Agricultural College, Palmerston North . .	8108	3003	2262	13,373	60·6	22·4	17·0
Dominant ryegrass/white clover under full return of animal residue trial, Palmerston North .	6300	4475	3459	14,234	44·3	31·4	24·3
Dominant ryegrass/cocksfoot, white clover under rotational grazing with dairy cows, Massey Agricultural College, Palmerston North	6473	4675	1630	12,778	51·0	36·0	13·0
Dairy pasture spelled November, July and August . . .	9013	3815	1675	14,503	62·0	26·0	12·0

demanding crops; this trend, forced upon the agriculturist by relatively low prices for his produce and his unwillingness thereby to utilize labour, is to be deplored, and must be rectified if real value is to be obtained from the spring periods of growth.

Some devices, apart from hay and silage, have been adopted in New Zealand to raise the summer and winter production from grassland; apart from the general use of wet stock and their natural increase coinciding with spring growth, autumn and spelled pastures are used for winter grazing *in situ*, and special summer pastures are common in which Italian ryegrass, Japanese millet and red clover are used. Paspalum in the north of the North Island affords good summer grazing. Rotational grazing with long spells between one grazing and another relieves the position in both summer and winter. None of these devices can, however, alter the fact that between 50 and 60 per cent of the total yearly production from high-quality grassland is

secured in one-third of the year; the only way that more of this feed can be utilized by grazing of the fresh herbage *in situ* is to increase the winter and summer-producing periods. Special winter and summer crops alone can do this.

One feels that the more efficiently one farms and the higher our grasslands produce, the greater is one's need for the fullest possible scientific information, on a dry-matter basis, of silage versus hay, versus dried grass, versus special winter and summer pastures, versus special winter and summer roots and forages, versus a grazing plan based on full utilization that envisages certain stock and production losses in extreme winters and summer droughts, versus a lenient grazing system where much roughage exists in the summer and well on into the winter. All the above systems are more or less in operation to-day, but there is little scientific evidence to guide us in future development as to the soundest course to follow.

High production per acre and high production per cow or per ewe are opposing concepts to which much thought must be given in all grassland farming. It is not wished to deprecate the great effort made to improve the production per animal by breeding and better feeding. Nevertheless, it is felt that, to exploit grassland fully and to maintain it over a long period in a highly nutritive state, more animals are required for pruning purposes on the farm than the grasslands can adequately support to the stage of achieving the peak of production per cow or per ewe. In other words, there are many times during the season when the grazing animal must be forced to clean up paddocks in order to maintain these in a highly nutritive and productive state throughout the growing season.

The maximum utilization by grazing by the most profitable conversion animal must be a basic concept in any plan of high production per acre, and there are many farmers to-day who are putting this principle into practice. Their country generally stands out, clean and well-grazed, with masses of stock, often concentrated in the one paddock. It cannot be denied that they run greater risks with their stock than the lenient grazier, more particularly in summer droughts and hard winters. Their need for vigilance and careful stock control following a drought in a season when warm autumn rains come is greater if serious losses from facial eczema are to be avoided, than where there has been lenient grazing and where much roughage in consequence persists on the farm. It is comparatively easy to farm in the lenient way: it is not so easy to judge carrying capacity to such a nicety as will fully exploit all feed grown to the best advantage without unduly penalizing the animal. This is the real test of efficiency in grassland farming.

More farm labour, and more winter and summer supplementary crops would materially help the full and efficient pasture utilizer to carry even more stock and to ensure less risk of stock losses during those low periods of pasture production which are inevitable and which lie beyond the skill of even the best of farmers to alter.

From the foregoing it will be seen that grazing management and pasture utilization dominate grassland farming in New Zealand. The hay and silage and any roots or forage crops that may be grown are for the most part fed out into grassland. Following this feeding out, harrowing to spread droppings

and to distribute any residues of wasted feed is generally practised on the dairy farm. Very little harrowing is done on sheep pastures. Tile drainage may precede the pasture sowing but usually mole drainage is carried out when the pasture has become consolidated. Levelling the surface to fill small hollows and to shear off the knolls greatly facilitates mole drainage. Top-dressing with artificial manures is widely practised and may be said to be the key to the initiation of the soil fertility cycle that is carried forward later by the residues of the grazing animal. Whereas Europe and Great Britain obtain their initial fertility rise largely by stock manures that are manufactured in normal times from home-grown and imported foodstuffs, New Zealand relies on imports of phosphate and its own limestone for the initial steps in the obtaining of fertility. An annual dressing of from 2 to 3 cwt. for fat lamb production and from 3 to 6 cwt. per acre per annum of a high-grade phosphate are normal applications on the dairy farm in the North Island where the climate is such as to present no limiting factor to the amount of phosphate that can be used. On the heavier soils 1 ton of carbonate of lime every 4 or 5 years is put on in addition to the phosphate.

Before the war New Zealand was using approximately 500,000 tons of phosphate, mainly in the form of superphosphate. In 1940-41, 4,649,317 acres of grassland were top-dressed, 2,923,378 with phosphate alone, 1,474,967 with lime and phosphate and 250,972 with lime alone.

By far the greater part of these top-dressings has been made on old-established grass, but emphasis is needed on the important place phosphate and phosphate and lime play in the early years of pasture establishment and development until such time as the full impact of the animal in large numbers is brought to bear. These two factors, together with the growing of strains of grasses and clovers that are efficient in their utilization, contribute most to the success of New Zealand grasslands.

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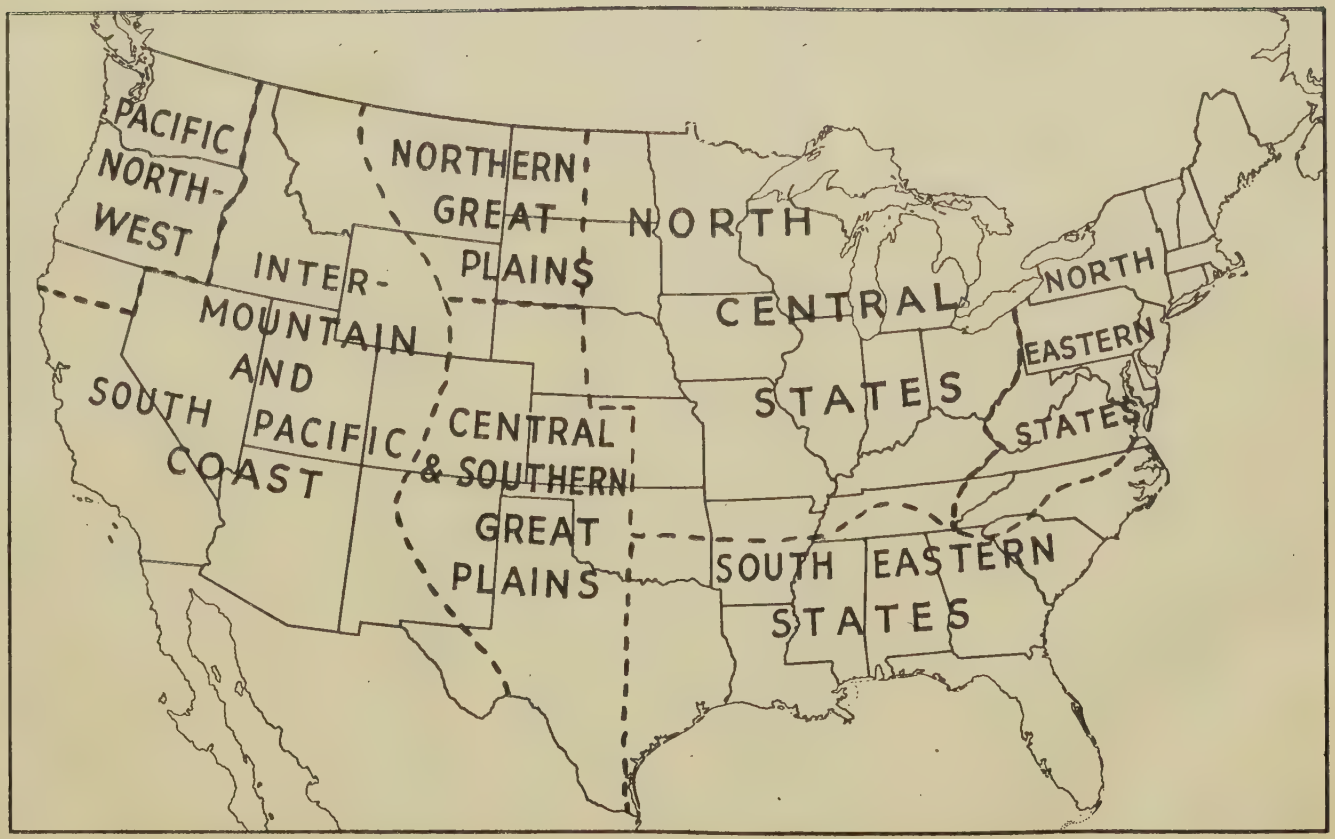

Map showing allocation of articles according to Regions, arranged by Dr O. S. Aamodt.

Vance G. Sprague and
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UNITED STATES OF AMERICA

Northeastern States

Introduction

Recommendations and procedures for the establishment of forage grasses and legumes to be used either as hay or pasture are dependent upon numerous environmental factors such as climate, topography, soil type and soil fertility and also upon such other general factors as the size and requirements of the farm, the economic aspects of the procedure and the interest and ability of the farmer to integrate and solve the details of his specific problems. In order better to understand the reasons for the recommendations and procedures and the species used, a very general description of the conditions affecting growth and plant usage throughout the region is presented.

The climate of the northeastern section of the United States including the States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania, West Virginia, Delaware, New Jersey and Maryland is classified as humid. The rainfall for the region as a whole approximates 40 inches although, due to a diversified topography of low mountains, rolling hills and valleys, there may be considerable local variation. The temperature throughout the region varies considerably from the areas along the coast with a maritime climate to those farther inland which are subjected to greater extremes. In the northern States of Maine, New Hampshire and Vermont the winter temperatures are low and the snowfall is abundant, while in the more southern States of the region along the Atlantic Coast the winter precipitation is largely rain or snow of short duration. The summer temperatures are not excessive, although along the seacoast of the States in the southern part of the region the humidity frequently is high, which makes the climate somewhat oppressive.

The climate of the region as a whole may be considered favorable for the growth of forage grasses and legumes. The combination of moderate summer temperatures and, in general, well-distributed precipitation provides growing conditions suited to such legume species as red clover, alsike clover, Ladino clover, white clover, alfalfa, sweet clover, birdsfoot trefoil and lespedeza, and to such grasses as timothy, Kentucky bluegrass, Canada bluegrass, redtop, Colonial bentgrass, orchard grass, meadow fescue, perennial ryegrass, smooth bromegrass and reed canary grass.

The soils of this region are extremely variable both in the southern half of the region which is composed of residual soils and the northern half which has been glaciated. While many of the pasture soils may be unproductive at present due to erosion losses, leaching and exhaustive farming, they are for the most part potentially productive and will respond markedly to lime and fertilizer. The lands used for permanent pasture are largely those on the steeper slopes or rocky areas which are now difficult to plow but which have been seeded to pasture or cleared and allowed to become pasture by the natural ingress of adapted species such as white clover and Kentucky bluegrass on the better soils and Canada bluegrass, poverty grass, broom sedge, bentgrasses and weeds on the poorer soils. In the southern part of the region lespedeza is becoming more common. The hay and meadow lands are largely

on the more level areas and in river bottoms. It is on these latter areas where most of the intensive seeding and management is practiced.

Use of Forage Crops

The most intensive use of cultivated forage grasses and legumes is for hay, although there is a rapid increase in the use of these species for silage and for carefully managed high-yielding pastures. The market milk areas near the large cities have seen the greatest increase in the intensive use of pasture and hay lands. The more remote and rougher areas, particularly in West Virginia and parts of Pennsylvania, New York and Maryland, are devoted more to beef cattle and sheep production rather than to dairy products. With the variability in land type and usage, it is difficult to present general practices for the establishment and early management of grass-legume mixtures which would meet the numerous detailed conditions presented. However, an attempt is made to approximate recommendations which generally prevail.

Establishment of Grass-Legume Mixtures

The methods employed in seed-bed preparation depend on several factors. These may be more easily considered if the land types are grouped into three general categories :

(1) those areas regularly in the crop rotation or which by topography could be so utilized,
(2) those areas too tough, stoney or steep to be included normally in the regular crop rotation, and
(3) those areas which, due to rocks or other factors, are not generally adaptable to tillage in any form.

Areas in the Crop Rotation

The largest part of the areas seeded to forage grasses is used for hay and meadows. In the southern half of the region the land is usually plowed, disked, and winter wheat (or winter barley, where it is adapted) seeded. Fertilizer (2-12-6 or 3-12-6) is usually drilled in with the wheat at rates of 300 to 500 pounds per acre. When timothy is used, this is often seeded with the wheat at 6 to 10 pounds per acre. The following spring, in early March, while the surface is still freezing and thawing, red clover and alsike clover are commonly broadcast in the wheat at rates of 8 to 10 pounds and 4 to 6 pounds per acre, respectively. Ladino clover has recently been added to the legume mixture in an attempt to maintain production during the third year after the red clover has largely disappeared. The wheat is usually cut for grain although it may furnish a small amount of early grazing without seriously reducing the yield of grain. In Delaware and parts of Maryland and West Virginia lespedeza may be broadcast on the winter grain at rates of 20 to 30 pounds per acre to furnish midsummer and fall pasture after the grain is removed.

In the more northern parts of the region, where winter grains are not adapted, the land is usually plowed, spring disked and harrowed and the forage seeds broadcast and lightly harrowed or cultipacked to cover the seed.

Fig. 44.—Pasture mixture 4 years after seeding, mown frequently to correspond to grazing conditions, shows effect of fertilizer treatment on the character of the sod. This plot received no fertilizer. Beltsville, Maryland.

Fig. 45.—Pasture mixture mown frequently to correspond to grazing conditions, showing effect of fertilizer treatment on the character of the sod. This plot received lime, phosphate and potash. Beltsville, Maryland.

Fig. 46.—Typical old permanent pasture in good production in the Northeastern Region. Montrose, Pennsylvania.

Fig. 47.—Reed canary grass pasture at Beltsville, Maryland.

When fertilizer is applied (recommended rates range from 300 pounds of 2-12-6 or 4-12-4 upward), it is broadcast before disking to work it into the soil. A spring grain such as oats or barley may be used for a companion crop or it may be omitted if summer pasture is desired and there is little or no danger of erosion. Depending on the farmer's requirements and the weather, the grain crop, when used, may be removed for hay, silage or mature grain. It may also be grazed if care is taken that the cattle are not turned in when the soil is too wet. If moisture is limiting, it is particularly advisable to remove the companion crop early and avoid the rapid depletion of soil moisture caused by the grain crop after it has reached the head stage. If no companion crop is used, a fair growth of the grasses and legumes is usually obtained by midsummer so that careful grazing may be practiced at this time. If annual weeds become serious, clipping at 4 to 8 inches will reduce competition on the new seeding. Where a companion crop has been used, whether it be a winter or spring grain, the amount of growth obtainable for midsummer pasture is greatly reduced.

Areas not Suited for Use in the Regular Rotation

Land which is too rough, too poorly drained or not otherwise suited for use in the regular rotation is usually used for long-time leys or permanent pastures. In some instances this type of land occasionally may be plowed and in this case methods of establishment and early management are similar to those used on the better lands except that once a sward is established it is not plowed again for some time. Subsequent improvement in the yield and nutritive value of the herbage on such areas is obtained by top-dressings of lime, superphosphate and potash and manure.

Another procedure, more promising for many areas where plowing is difficult or hazardous from the standpoint of erosion, is becoming more widely accepted. This involves the use of such implements as the cutaway disk, field disk, spring-tooth harrow or field cultivator, which will work up the land but do not turn the sod under. This provides an organic mulch in the surface layer which prevents serious erosion and provides a physical condition of the surface favorable for moisture penetration and germination of the seeded forage species.

Since in establishing grasses and legumes by this method (in many areas known as "renovation") the first objective is to kill or severely weaken the vegetation on the area, consideration must be given to the climatic conditions which may be expected during the weeks following the disking. During late summer or fall there are often periods of dry weather which provide conditions most effective for killing or weakening the vegetation after disking. Following a shower of rain, the area is worked again to loosen the plants from the soil and prevent renewed growth.

Lime is applied in sufficient quantity to meet the lime requirement before any cultivation is begun. This is followed by disking a sufficient number of times to sever the roots of the existing vegetation. Just prior to the last disking, phosphate and potash fertilizers are applied and harrowed in. In most instances the land remains in this condition over winter and the seed is broadcast early the following spring, as soon as the snow is gone, while the surface is alternately thawing and freezing, thus covering the seed. A companion crop of a spring

grain such as oats or barley may be seeded but more often the grasses and legumes are seeded alone. Where a companion crop is used it is often grazed off or cut for hay, and the grasses and legumes may provide limited grazing later in the summer. Where no companion crop is used, a fair growth can be expected in late July or August for limited grazing. However, here as elsewhere, grazing should not be so close or late as to prevent the new seeding from going into the winter with a good top growth present.

The amounts of phosphate and potash fertilizer applied depend to a large extent upon the soil type and its fertility level and in many instances up to 100 pounds of P_2O_5 and 50 to 100 pounds of K_2O are recommended. The adaptable species of grasses and legumes vary according to soil type, climate, and expected use. In the northern parts of the region for high-yielding pastures on upland soils which will be carefully grazed, timothy is strongly recommended as the grass, although orchard grass and smooth bromegrass are being used in limited amounts and may increase in importance, particularly if better adapted strains are produced. Ladino clover and red clover are the most important legumes which are seeded with the grasses, although birdsfoot trefoil appears to be adapted. In the other parts of the region, timothy, while widely used, does not produce as well during midsummer as orchard grass and bromegrass and is often seriously affected by disease. Ladino clover, red clover and alfalfa are recommended for use with these grasses. On the lower, wetter lands, meadow fescue, reed canary grass, alsike clover and Ladino clover are species often found best adapted.

On pastures in the southern part of the region where the soil may be slightly acid and the sod not too heavy, lespedeza may be established by a light harrowing in the spring followed by broadcasting the seed at rates of 20 to 30 pounds per acre. Top-dressing with phosphate at rates of 40 to 80 pounds P_2O_5 per acre substantially increases the yield. Lespedeza, when once established, reseeds itself when competition from the grasses or white clover is not too great.

While there are many differences of opinion regarding the seeding rates of the above species, the following mixtures and rates of seeding may closely approximate the general recommendation. Where the pastures are not intended to be used intensively and where careful management is not contemplated, Kentucky bluegrass, redtop and white clover may be added to the mixture. These species will persist after the other species have largely disappeared, and, while the resulting pasture may not be as productive as that produced by the larger growing species, a sod cover will be maintained even under rather lax management practices. When seeded in simple mixtures, the seeding rates of the more commonly used species are :—

	Pounds per acre		*Pounds per acre*
Timothy	4 to 6	Ladino clover	1 to 2
Orchard grass	6 „ 8	Red clover	8 „ 10
Bromegrass	10 „ 12	Alsike clover	4 „ 6
Reed canary grass	8 „ 10	Alfalfa	8 „ 10
Meadow fescue	8 „ 10	Birdsfoot trefoil	4 „ 6
Kentucky bluegrass	6 „ 10	White clover	1 „ 3
Redtop	4 „ 6	Korean lespedeza (seeded alone)	20 „ 30
Perennial ryegrass	6 „ 10		

Areas too Rough for the Use of Tillage Implements

The land in the northeastern United States which is so rough, steep or stoney that even the use of the disk or spring-tooth harrow is questionable is more often managed as a wood lot to provide fence posts, fuel or lumber. There are instances, however, where this poorer land must be used for pasture. The methods of establishment of grasses and legumes under such conditions depend largely on the addition of fertility amendments to the soil and continuous grazing. By increasing the soil fertility and grazing to keep down weeds and brush, Kentucky bluegrass and wild white clover will usually become established from seed or vegetative nuclei which are almost omnipresent in the northeastern States. Broadcasting seed of Kentucky bluegrass, redtop and white clover in the early spring may often aid in the establishment of a sod. Pastures thus established will not be as high-yielding as those consisting of species such as Ladino clover in association with bromegrass, orchard grass or timothy, nor will they continue to produce as well during the drier, warmer summer months.

Summary

The northeastern section of the United States is favored with a climate conducive to the growth of forage grasses and legumes. Temperature extremes are not as great as those farther inland and rainfall is in general adequate for growth.

Soils in the region are generally acid and may often be low in available phosphate, potash and nitrogen but respond well to applications of these elements. The topography is largely rolling and often rough. Thus a large part of the region is better adapted to a grassland type of agriculture than to crops requiring more tillage.

The more intensive pasture and hay lands are included in the regular rotation on plowable lands, and are often spring-seeded in winter grains where such are grown or in spring grains in the northern part of the region. Red clover and timothy and alfalfa are the most important hay plants, although increased use is being made of alfalfa and bromegrass, and alfalfa and orchard grass (often with the inclusion of Ladino clover) for hay or silage followed by aftermath grazing.

Where plowing is difficult, it is recommended that these areas be worked in midsummer with a heavy disk or spring-tooth harrow to kill the existing vegetation, limed, fertilized liberally with phosphate and potash and then spring seeded often to either Ladino clover and red clover with a grass such as timothy, orchard grass or bromegrass. On poorly drained areas reed canary grass, meadow fescue, redtop, alsike clover and Ladino clover are being used.

The larger growing grasses and legumes are used primarily where a high yield of nutritious herbage is desired and where careful grazing management can be practiced. Where grazing cannot be carefully controlled, Kentucky bluegrass and white clover may be included in the mixture to form the sward after the larger growing species have disappeared.

The pastures on non-tillable areas are improved by top-dressing with lime, phosphate and potash. In most instances a fair sod of Kentucky bluegrass and white clover will become established from volunteer seed and plants after two to four years' time.

R. L. Lovvorn*

UNITED STATES OF AMERICA

Southeastern States

The southeastern region of the United States extends from the Atlantic Ocean to approximately 96° West longitude and from the Gulf of Mexico to approximately 37° North latitude. This area includes the States of Virginia, Kentucky, Arkansas, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and the eastern part of Texas. The mean annual temperature varies from approximately 55° F. on the northern edge to 75° F. on the southern end of Florida. The average January temperature is between 35° F. and 70° F. Most of the region receives from 45 to 60 inches of rainfall annually.

Most of the soils within the region are in the Red and Yellow Podzolic group. The relatively high rainfall and warm temperatures have resulted in strongly leached soils that are acid in reaction and low in organic matter and mineral plant nutrients. The predominating soils have a light colored sandy surface with a heavier red or yellow subsoil in their virgin state, but many of them have their subsoil exposed due to erosion. Their light texture makes them easy to cultivate. Although low in available nutrients, they do respond markedly to fertilization.

Cotton has been grown extensively in this region for many years, and the characteristic agriculture has been one of "row-cropping." The important crops have been cotton, corn, tobacco, horticultural crops, soybeans and cowpeas. The rolling topography and the lack of sod crops in the rotation have resulted in serious erosion over much of the region. Except in localized areas, livestock have been relatively unimportant until recently, and the pasture acreage is still a small percentage of the total crop acreage. More recently, however, the livestock numbers have been increasing and parallel with this development has been a greater interest in pasture development and pasture research. The native vegetation is largely forest. None of the native grasses have been used in improved pastures.

Permanent Pastures

Preparation of the seed-bed

The kind of seed-bed preparation depends upon the machinery that is available and the amount of crop residues on the land. It is now generally considered that deep plowing is unnecessary. A thorough disking with a bush and bog disk will break the surface soil to a sufficient depth to give a good seed-bed and will also leave much of the crop residues on the surface; these residues serve as excellent mulching material. Workers at the Mississippi Station (Mississippi A.E.S., 1940-41) have found that the stand of the grass-legume mixture is greatly influenced by the amount of seed-bed preparation. The procedure usually recommended is to follow the bush and bog operation with a tandem disk and spike-toothed harrow. The seeds are sown either by hand

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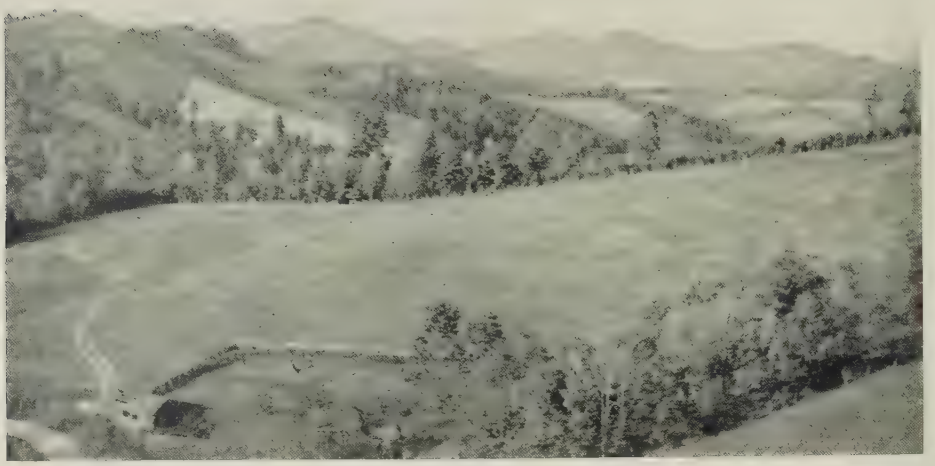
Fig. 48.—Coastal plains. Topography : level to undulating. Soils : sands and sandy loams.

Fig. 49.—Piedmont. Topography : rolling. Soils : clays and clay loams.



Figs. 50 and 51.—Appalachian Mountains. Topography: steep. Soils: clays and clay loams.

or with a small seeding attachment on the grain drill ; the land is then rolled with a cultipacker. A seeding attachment has recently been developed for drilling small-seeded legumes between the two rollers of a cultipacker that should result in lower rates of seeding (Wisconsin A.E.S., 1939).

Depth of planting

Moore (1943) has studied the emergence of small-seeded legumes and grasses more extensively than any other worker in the Southeastern United States. He found that small-seeded species gave better emergence when planted to a depth of 0·25 to 0·5 inch. The plants that did emerge from deeper plantings were much weaker and less able to compete with weeds. The several crops showed wide differences in the percentage of emergence at the various depths. The lespedezas were much less tolerant of the deeper depths than were alfalfa and the true clovers.

Mulching

Stands of legumes and grasses are greatly affected by the use of plant residues as mulching material. This has been particularly noticeable on eroded areas in which the water-holding capacity is low. Annual lespedezas have been reported to yield as much from eroded areas that were mulched as from nearby uneroded land that was not mulched (Hendrickson and Crowley, 1941). The lespedeza was a complete failure on the eroded non-mulched plots. Emergence of other species has also been greatly improved by mulching (Moore, 1943). The beneficial effects of surface mulching are (1) higher and less variable moisture content, (2) less variation on the soil temperature, and (3) less soil compaction by rainstorms. Because of these advantages, species are able to tolerate a greater range in planting conditions when mulched. The more obvious advantages are a greater spread in seeding depths and dates. Seeding operations on areas such as road shoulders and airfields have to be done when completed regardless of the date, and it is under such conditions that the effects of mulching become particularly beneficial. Any crop residues may be used provided the rate is not sufficiently heavy to smother the seedlings. One to two tons per acre are sufficient.

Many of the soils are so severely eroded that satisfactory stands of grass cannot be obtained. Under such conditions lespedeza will make considerable growth if fertilized. The effects of this leguminous crop upon the chemical and physical properties of the soil make it possible to establish stands of perennial grasses after 1 or 2 years.

Companion crops

There is no general agreement among agronomists in the Southeastern United States as to the use of companion crops with legumes and grasses. A companion crop appears to be desirable on land that is heavily infested with weed seeds. During periods of drought, however, a companion crop may be more harmful than beneficial because of the competition for moisture. The small grains are usually used as companion crops ; their differential effect on

the yield of lespedeza hay is illustrated by the following results obtained by the North Carolina Agricultural Experiment Station :—

Yield of Lespedeza Hay (in pounds per acre) following

Oats	2500
Wheat	3500
Barley	4500

In areas where a companion crop appears to be needed, no more than one-half the normal seeding rate of the companion crop is recommended. The companion crop should be cut for hay, or even harvested prior to that time in the event of a period of extreme moisture deficiency.

Species adapted

Bermuda grass (*Cynodon dactylon*), carpet grass (*Axonopus affinis* Chase) and Dallis grass (*Paspalum dilatatum* Poir.) are the three permanent pasture grasses most extensively grown in the region. Carpet grass is persistent and aggressive on moist sandy soils and often appears spontaneously when the land has been cleared and grazed heavily. It endures close grazing very well, but is not very productive. It is not considered to be as nutritious as Bermuda grass or Dallis grass, and makes such a close turf that legumes cannot be maintained with it. Since legumes are considered essential in the pastures of the region, many agronomists are not recommending carpet grass in new seedings. This is particularly true in the northern portion of the region. Blaser, Kirk and Stokes (1942) have worked extensively with carpet grass in Florida, and apparently under their conditions it is one of their best grasses.

Dallis grass, although less abundant than either carpet grass or Bermuda grass, is becoming of increasing importance as a grazing plant. It is a long-lived perennial with a semi-upright habit of growth that permits the satisfactory growth of legumes. Lovvorn (1942) has shown that lespedeza, a legume quite sensitive to grass competition, grows better in association with Dallis grass than with either carpet grass or Bermuda grass. Dallis grass is more nutritious and productive than carpet grass and does not become a pest in cultivated fields as does Bermuda grass. The grass is usually attacked by ergot (*Claviceps paspali*), and seed of poor quality results. Even though seed imported from Australia and New Zealand also contain the ergot they are of a higher quality than those produced in the United States. Imported seed are usually used when available. The presence of ergot in the seed heads has been known to cause poisoning of cattle if eaten in any quantity, but apparently this poisoning is infrequent. The grass is subject to winter killing in the northern portion of the Southeastern region and throughout the higher altitudes of the Southern Appalachian range.

Bermuda grass is used as a permanent pasture throughout the region. It is more winter hardy than either carpet grass or Dallis grass, which means that it grows farther north than the other two grasses. It is not adapted to the poorly drained soils in which carpet grass grows so vigorously but is particularly suited to the sandy soils in which moisture is often a limiting factor. Since Bermuda grass develops extensive rhizomes and stolons and is propagated vegetatively as well as by seeds, the grass may become a pest if grown on land

in rotation with cultivated crops. Its ease of establishment, in addition to its tolerance of a wide range of soil fertility levels and management practices, explain its widespread use throughout the Southeastern United States. The dense turf that is formed is also resistant to heavy traffic, and it is used more extensively on airfields and athletic fields than any other grass in the region. A new strain, Coastal Bermuda grass, has been developed by Burton (1943). The improved strain has larger stems, stolons and rhizomes than common Bermuda grass. Its leaves have a characteristic light green color and are much larger than the common variety. Coastal Bermuda grass also produces very few seed heads and those that are produced rarely contain viable seed. Since Bermuda grass is usually propagated vegetatively, the poor seeding habit of the Coastal strain is considered an advantage in that the seed are not disseminated in the manure. The improved strain also produces more vegetative yield than common Bermuda grass and can be used for either grazing or hay.

Bermuda grass is often propagated vegetatively. According to Burton (1943) the stolons should be planted 4 to 6 inches deep in rows in well-prepared land. Various machines modeled after tobacco planters have been devised to reduce the labor required for the job. The greatest weakness of these machines has been their inability to plant the stolons and rhizomes deep enough. The vegetative parts should not be allowed to dry before planting.

Bahia grass (*Paspalum notatum* Flugge) is another Paspalum that is receiving some attention as a forage plant in the region. Several strains, either from selection or introduction, are now available and the acreage is increasing. This grass seems to have the ability to grow on dry, sandy soils that are adapted to Bermuda grass.

Other grasses that are grown only in Southern Florida are Para grass (*Panicum purpurascens* Raddi), molasses grass (*Melinis minutiflora*) and Natal grass (*Tricholaena rosea*).

Not all the grasses grown in the Southeastern United States are strictly "warm weather" plants. Redtop (*Agrostis alba*), orchard grass (*Dactylis glomerata*), and Kentucky bluegrass (*Poa pratensis*) are also grown extensively in the northern portion of the region, particularly in the States of Kentucky, Virginia, Tennessee and western North Carolina. Redtop is not a very nutritious grass but is often seeded because of its ability to grow on soils that are low in productivity or poorly drained. Orchard grass will grow on soils of medium fertility and, if not overgrazed, is more productive than Kentucky bluegrass. It establishes itself quickly, and usually the sod can be grazed the first year after seeding. Kentucky bluegrass is the predominating grass of the more northern portion of the region. It will tolerate closer grazing than orchard grass but requires a fairly productive soil. It is slow to establish itself, and usually the sod cannot be grazed in the first year after seeding.

Lespedeza is the most important legume of the region. Both *Lespedeza striata* (Kobe and Common) and *L. stipulacea* (Korean) are grown extensively. The adaptation of Korean is farther north than the Kobe (Grizzard and Hutcheson, 1940). Kobe is grown successfully on some of the sandy soils of Florida. Usually, however, the lespedezas are not adapted to extremely sandy soils. Korean, Kobe and Common are all annuals but reseed naturally and therefore maintain themselves in the sod. The Common is a smaller variety

and will tolerate closer grazing and grow on poorer soils than either Kobe or Korean. It is not so productive, however.

White clover (*Trifolium repens*) is grown throughout the region. It requires a more productive soil with a higher calcium level than is needed for the lespedezas. It produces grazing much earlier than the lespedezas but is not generally as dependable year after year. White clover behaves as a perennial in the northern portion of the region and as a winter annual farther south. It seems to be able to compete more successfully with grasses than do the lespedezas.

Low hop clover (*Trifolium procumbens*) has been grown experimentally throughout much of the region but has never become widespread as a pasture species. It has been very promising as an early spring grazing legume at the Middle Tennessee Experiment Station and in the Coastal Plain of North Carolina. California bur clover (*Medicago hispida* Gaertn.), black medic (*M. lupulina*), and Persian clover (*T. resupinatum*) are being used in Florida, but they have never been grown extensively elsewhere in the region.

Mixtures

The characteristics of the several permanent pastures have been briefly discussed above. The State agricultural experiment stations within the region vary as to the seeding mixtures they recommend. A few recommendations are as follows (rates quoted in pounds per acre) :—

Arkansas (Nelson, 1934):

Bermuda grass
Lespedeza
Hop clover
Bur clover
White clover

Tennessee (Mooers, 1938).

Medium Upland		*Fertile Upland*	
Kentucky bluegrass	6	Kentucky bluegrass	4
Orchard grass	8	Orchard grass	8
Redtop	4	Redtop	4
Alfalfa	6	Alfalfa	6
Red clover	6	Alsike	2
White clover	1·5	Red clover	6
Lespedeza	5	White clover	1·5
Low hop clover	1·5	Lespedeza	5
		Low hop clover	1·5

North Carolina (Woodhouse and Lovvorn, 1942):

Coastal Plain		*Piedmont and Mountain*	
		A. Medium to good soils :	
Dallis grass	10	Kentucky bluegrass	5
Redtop	2	Redtop	5
Lespedeza	15	Orchard grass	5
White clover	1	White clover	1 to 2
		Lespedeza	15
		B. Poor to medium soils :	
		Redtop	6
		Orchard grass	6
		Dallis grass	4
		Lespedeza	15

Georgia (Bledsoe and Sell, 1940):

Upland Piedmont	*Bottomlands*
Bermuda-hop clover-lespedeza or	Dallis grass-Bermuda-lespedeza or
Bermuda-crimson clover or	Dallis grass-Bermuda-white clover-
Bermuda-white clover	lespedeza

Florida (Blaser and Boyd, 1940):

Low wet sandy acid soils		*Moist drained sandy acid soils*	
White clover	3 to 5 or	White clover	1 to 2
White clover	2 „ 3 and	California bur	8
Persian clover	1 „ 3	Black medic	3

Three to 6 pounds of redtop or 5 to 7 pounds of Italian ryegrass are recommended with the above clovers. Carpet grass establishes itself in Florida without seeding.

Alabama (Alabama A.E.S., 1934):

Dallis grass	10
Common lespedeza	10
Low hop clover	1

Dates of seeding

Orchard grass, Kentucky bluegrass and redtop are usually seeded in the fall, although they can be seeded in the early spring if the competition from weeds is not too great. Dallis grass and carpet grass are usually seeded in the early spring, although the Mississippi Experiment Station (Mississippi A.E.S., 1940-41) recommends fall seeding of Dallis grass. Bermuda grass seed are planted in the early spring, or the plant may be planted vegetatively throughout the spring and summer.

The annual lespedezas are seeded in February or March, whereas white clover may be seeded either in the fall or spring. If seeded in the fall, the optimum date varies from September in North Carolina and Virginia to November in Florida. The winter annual legumes such as low hop, bur and Persian clovers are seeded in the fall.

Seed scarification

It is often difficult to obtain satisfactory stands of some of the southern grasses. This has been particularly true of some of the *Paspalum* species. Burton (1940*a*) found that, regardless of the manner in which the seed of Bahia were planted, acid scarification greatly increased the number of plants per pound of seed. Proper acid scarification enabled this species to germinate as readily as Dallis grass or carpet grass. Even though it is sometimes difficult to obtain stands of Dallis grass, it does volunteer readily. Ray and Stewart (1937) have shown that either puncturing or removing the lemma and palea was effective in increasing the germination of Dallis grass. Immersing the seed in hydrochloric acid for 5 minutes also increased the germination, but not to the extent of the removal of lemma and palea. The acid scarification method is considered the more practical of the two. Ray and Stewart (1937) attempted to explain the poor stands of Dallis grass as due to the impermeability of the seed coat to moisture until late in the summer, and to the late seedlings being unable to compete with earlier germinating species.

White clover behaves as a winter annual in the southern part of the Southeastern United States in some years. Under such conditions the seeds that mature in the spring germinate the following fall. White clover seeded in the early fall can often be grazed earlier than from natural reseedings Burton (1940*b*) has corrected the delayed germination characteristic by means of seed scarification. He concluded that the ability of white clover seed to germinate was closely associated with its ability to absorb moisture.

Fertilization

The fertilization of permanent pastures in the Southeastern region depends somewhat upon the species that are utilized. Bledsoe and Sell (1940) have shown that pasture species, particularly the legumes, vary in their nutritive requirements. Since legumes are considered as one of the essentials in a pasture sod, the fertilizer requirements of the legumes must be provided first. Phosphorus and calcium are usually the first limiting factors in legume production. Potassium is often needed in the heavier soils and usually needed in the sandy soils of the Coastal Plain. The returns from nitrogen fertilization have been less than from the other three fertilizing elements. Some of the agricultural experiment stations are recommending that nitrogen be included in the fertilizer applied at seeding to stimulate the grass seedlings, even though it is realized that heavy applications will stimulate the grasses at the expense of the legume population.

The North Carolina Station recommends an application of 500 pounds of an 0-14-7 fertilizer at seeding ; this amount is considered sufficient for a 3-year period. Other stations having similar soil and climatic conditions recommend similar fertilizers. The amount of limestone to be applied is determined by soil tests, but in actual practice approximately 1 ton per acre is usually applied except on the heavier soils. Much heavier rates of application of fertilizer are necessary on the sandy soils of Florida. Annual applications of 600 pounds per acre of either an 0-16-8 or a 3-16-8 fertilizer are recommended.

Pasture species have also responded to treatments of copper, zinc, manganese and boron on the Florida soils. Very little work on the effects of minor elements on legumes and grasses has been done in the other States of the region, and it is possible that other soils will be shown to be deficient in these nutrients.

Management

Grazing of the new seedings weakens both the top and root growth, thereby lessening the chances for a satisfactory stand. Woodhouse and Lovvorn (1942) have shown in greenhouse experiments that defoliating Dallis grass at 10, 20, and 30-day intervals resulted in yields of 0·98, 2·07, and 2·82 grm. respectively, whereas carpet grass yielded 0·81, 1·17 and 1·31 grm. respectively under the same treatments. Seedings made in the fall may be grazed lightly the next year provided overgrazing is not practiced at any time. Spring seedings should not be grazed the first season unless the growth has become so excessive that the legumes are receiving severe competition from the grasses. Mowing the new seedings a couple of times during the year to control weeds has been demonstrated to be very advantageous. Allowing a rest period either in the

spring or fall has increased the ratio of Dallis grass to carpet grass when the two were grown together.

There are many acres of virtually pure stands of carpet grass throughout the moist, sandy soils of the Southeastern United States. The productivity of these pastures could be greatly increased by the introduction of legumes. They could be introduced by fertilization, accompanied by cutting the sod with a disk and seeding either lespedeza, white clover or low hop clover. Due to the dense habit of growth of carpet grass it may be necessary to redisk and reseed the legumes every few years.

Supplementary Pastures

There are many crops that can be utilized for grazing in the Southeastern United States, but the ones more extensively used are Sudan grass, Johnson grass, cattail millet, the small grains, kudzu, lespedeza and soybeans. All of them require a well-prepared seed-bed. The preparations consist of either plowing or deep disking, followed by a light disking and harrowing or rolling. Since the primary purpose of supplementary pasture crops is to provide grazing during critical stages in the permanent pasture grazing program, these crops are often seeded on productive land and heavily fertilized. The exceptions will be discussed under the individual crops.

Sudan grass (*Sorghum vulgare* var. *sudanense*) may be either broadcast or seeded in narrow rows and cultivated. The latter method has proven to be more satisfactory where competition from annual weeds is severe. The crop is fertilized with a complete fertilizer at planting and given one or two applications of commercial nitrogen as a top-dresser. The latter applications vary from 15 to 30 pounds of nitrogen per acre. Sudan grass will give the greatest production if two or more fields are grazed alternately, allowing the erect plants a rest period in which to make new growth. The crop may be grazed when it is 18 to 24 inches high but is palatable and readily eaten in the early heading stage. It is an annual and must be reseeded each year.

Johnson grass (*Sorghum halepense*) has been considered a pest because of the difficulty of eradication. More recently, however, it has become recognized as a valuable grass in the Black Belt section of Alabama and Mississippi. It is not only useful as a supplementary grazing crop during drought periods in the summer and fall but is also grazed during the winter months. The perennial will maintain itself indefinitely if fertilized and not overgrazed.

Cattail millet (*Pennisetum glaucum*) is grown and used in a manner similar to that of Sudan grass. This millet will be ready for grazing in a shorter period of time than Sudan grass. It is not as palatable, however, and the coarse stems cause it to be unsuitable as a hay plant. Both are summer annuals that provide grazing from early summer until frost.

The small grains are seeded in September and October and may be grazed lightly during the fall, winter and early spring. The animals are then removed and a grain crop allowed to produce, or the crop may be grazed completely out. The former system of management is the usual procedure. Barley, wheat, oats and rye are used, either singly or together. Either vetch (*Vicia* species) or crimson clover (*Trifolium incarnatum*) may be seeded with the grains. Experiences in the northern portion of the region, the area in which

small grains seem to be better adapted, indicate that on fertile soils barley will provide more fall grazing, rye more winter grazing and wheat more grazing in the spring. Rye and oats are better suited to the less fertile soils than barley or wheat. If seeded alone, or with a legume only, the seeding rates per acre are 3 bushels of barley, 1·5 bushels of wheat, 1·5 bushels of rye and 4 bushels of oats. A complete fertilizer should be applied at the time of seeding in the fall and a nitrogenous fertilizer as a top-dresser.

The annual lespedezas are ideally suited to a small grain-lespedeza rotation. Lespedeza is seeded on the fall-seeded small grain in February or March either with a grain drill or broadcast. Seeding with a grain drill is preferable. The seeding rates vary from 25 to 40 pounds per acre, depending upon the variety. The Kobe seed are larger than the Korean. Lespedeza responds to soil treatments of limestone, phosphate and potash and these materials should be provided unless they have been added to the small grain the previous fall. If not overgrazed, the crop will provide grazing from July 1 until frost. Unlike the Sudan grass, rotational grazing is not necessary. The crop reseeds itself naturally, and once a seed crop is produced the crop will maintain itself indefinitely if properly managed. Small grain can be seeded after the lespedeza seed have matured and the lespedeza will volunteer the following spring. Wheat and rye are more suitable to this rotation than barley because they are seeded later, thus allowing time for the lespedeza seed crop to mature. It is not only used for grazing, either in pure stands or in the permanent pasture sward with perennial grasses, but is also an excellent hay crop. Its ability to grow on soils of medium to low fertility levels and its characteristic volunteering habits are responsible for its widespread popularity.

Kudzu (*Pueraria thunbergiana*) is the only supplementary grazing crop of widespread importance in the region that is a perennial. It appears to be adapted to all of the well-drained soils of the Southeast and has been grown primarily on the poor, eroded steep soils. Unlike most of the other forage crops of the region, kudzu is propagated by transplanting either crowns or seedlings. The usual method is to transplant crowns from some nearby field in which kudzu is growing. The crowns or seedlings are planted in rows 25 feet apart with 3·5 feet spacings between the plants. The ideal time to plant kudzu is in early spring just before active growth begins. It usually requires from 2 to 4 years, depending upon the fertility of the soil, for sufficient growth for grazing. During the time the stand is becoming established the land can also be planted to some cultivated crop. Applications of phosphate, and in some cases potash, are necessary. A light application of manure in the row at planting has also been found to be advantageous. Once a satisfactory stand is established the crop can be grazed from June until October, provided it is not overgrazed. The crop is best utilized, however, as a source of surplus forage that can be grazed whenever the permanent pastures become unproductive. This flexibility in grazing schedules is an advantage that none of the other supplementary grazing crops possess.

Soybeans (*Soja max*) may be planted either broadcast or in rows and cultivated. The latter method is preferable where the land is infested with annual weeds. Seeding rates vary from 30 to 50 pounds per acre, depending upon the size of seeds, when planted in rows. Broadcast seeding rates are about

50 per cent larger. The coarse-stemmed varieties are preferable for grazing because of their ability to tolerate livestock tramping. One of the popular varieties has been the Biloxi. A complete fertilizer low in nitrogen and high in potassium is desirable. The soybeans are usually grazed heavily until most of the foliage has been removed; the animals are then removed and plants allowed to recover. Gibson and others (1943) found that the soybean plant is physiologically capable of remaining productive in spite of wide variations in defoliation treatment and that the intensity of grazing may be varied according to particular needs without serious reduction in the total yield. It is an annual that does not volunteer and provides grazing during the summer and early fall.

The culture of Napier grass (*Pennisetum purpureum*) is confined almost entirely to Florida, but within that State it has proven to be a valuable grazing plant. It will not tolerate the winter temperatures farther north. It is a leafy perennial that grows 7 to 15 feet high. Improper management has been one of the most important factors limiting its use in Florida, according to Blaser and others (1942). Grazing animals should be removed when 75 to 95 per cent of the blades have been consumed. The rhizomes are planted in early spring in 8-foot rows and spaced 2 feet apart in the row. They are covered to a depth of 4 to 6 inches. Blaser and others (1942) recommend two cultivations the first year and an annual disking in February followed by one cultivation between the rows during the spring. Heavy annual applications of nitrogenous fertilizer are necessary.

Summary

The Southeastern region of the United States is characterized by mild winter temperatures, high rainfall and soils that are relatively low in mineral nutrients. Kentucky bluegrass, orchard grass and redtop are the predominating perennial grasses in the northern portion of the region. Dallis grass, carpet grass and Bermuda grass are used farther south. Since the last three grow at a higher temperature, they cannot be grazed any earlier even though the winter temperatures are milder in the area where they are grown. White clover is grown throughout the region and its ability to grow at lower temperatures than Dallis grass or carpet grass makes earlier grazing possible in warmer portions of the Southeastern region. Lespedeza is an important constituent of the sward throughout the region.

Fertilization is necessary for both the establishment and maintenance of satisfactory stands. Calcium and phosphorus are almost universally deficient, and it is usually necessary to apply potassium. Fertilizing and limestone materials carrying these elements can be applied either annually or every 3 to 5 years, provided adequate rates are given. Applications of nitrogen greatly stimulate the grasses but often at the expense of the legume in the sward. The greatest response from nitrogenous fertilizers has been on swards in which the legume population was low.

Many pasture seedings fail because of the low supply of available nutrients. Management becomes a factor only after the nutrients have been supplied. New seedings should be grazed only lightly, if at all, in the first year. In

subsequent years the sward should be mowed twice during the grazing season to aid in the controlling of undesirable species.

The supplementary crops adapted to the region are Sudan grass, cattail millet, small grain, lespedeza, kudzu and soybeans. With the exception of lespedeza, these crops must be grazed either rotationally or lightly if satisfactory yields are to be obtained.

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UNITED STATES OF AMERICA

North-Central Region

The north-central region of the United States comprising the States of Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan and Ohio is characterized by a diversity of soil and climatic conditions which prevails within each State as well as between the States. Prior to settlement by the white man the eastern portion of the area was covered with dense growths of coniferous and deciduous forests. The remainder of the area was occupied by tall-grass prairie. The western limit of the forested area crossed the Canadian boundary into eastern North Dakota, thence in a southeasterly direction into Illinois, and then in a southwesterly direction to Oklahoma.

The agriculture which has gradually evolved in this region since original settlement by the white man has been developed at the expense of the native species. Forested areas were cleared and the tall-grass prairies were plowed to make way for the species now commonly grown for feed and food. The present agriculture of this area is devoted largely to the support of an extensive livestock industry. Most of the plant products produced are utilized in connexion with dairying, beef, sheep, swine and poultry production and for the maintenance of horses and mules. Minnesota (excepting the southwestern portion), Wisconsin, Michigan and eastern Ohio are included in the hay and dairy region of the United States, whereas southwestern Minnesota, Iowa, Missouri, Illinois, Indiana and western Ohio represent an integral portion of the corn belt. Soft red winter wheat is also grown extensively in portions of Missouri, Illinois, Indiana and Ohio.

Forages for use as hay, pasturage, grass silage, green manure and seed production are integrally interwoven and are vitally important in the various farm enterprises of the entire area.

Soils Vary Widely

The prevailing soils (U.S.D.A., 1938) within the region may be classified into three primary groups as follows :—

1. *Podsols.* The profile of soils within this group consists of a very thin layer of organic matter above a gray leached layer which rests upon a dark brown or coffee-brown horizon. The podsol is developed under a coniferous forest in cool, moist climates. Its inherent productivity for crop plants is low. Extensive areas of soils within this group are found in the northern portions of Minnesota, Wisconsin and Michigan.

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2. *Gray-brown podsolic soils.* The profile of these soils has a rather thin layer of organic matter over grayish-brown leached soil which overlies a brown horizon. The soils are generally acid, at least at the surface; they develop in moist and cool, temperate climates under a deciduous forest and are inherently more productive than the podsols. Soils of this group are found in Minnesota, Wisconsin, Ohio, Illinois, Indiana and Missouri.
3. *Prairie soils.* The profile of the prairie soils grades from a very dark brown or dark grayish-brown surface through brown to lighter colored parent material at a depth of 2 to 5 feet. It is developed in a moist, temperate climate under a tall-grass prairie. The inherent fertility of these soils for crop plants is high. Extensive areas of soils of this group exist in Minnesota, Illinois, Iowa and Missouri.

Climatic Conditions

The general climatic conditions (U.S.D.A., 1941) which prevail in the region are given in Table 1. The data indicate that rainfall conditions are generally favorable for the growth of forage grasses and legumes throughout

Table 1

Climatological Data for the North-Central Region

State	Average range in annual precipitation (inches) within State	Average range in January temperature (F.) within State	Average range in July temperature (F.) within State	Average number of days without killing frosts (range within State)	Average date of last killing frost in spring (range within State)	Average date of first killing frost in fall (range within State)
Wisconsin	28-32	10-22	66-72	90-170	April 30-June 5	Sept. 10-Oct. 20
Minnesota	20-32	0-16	60-74	100-160	April 30-June 5	Sept. 10-Oct. 5
Michigan	26-36	10-26	60-72	80-180	April 25-June 10	Aug. 30-Oct. 20
Ohio	32-44	24-34	72-76	140-200	April 10-May 10	Oct. 5-Oct. 20
Indiana	34-46	26-34	74-78	150-190	April 15-May 10	Oct. 5-Oct. 20
Iowa	26-36	14-24	72-76	140-170	April 25-May 15	Sept. 30-Oct. 10
Illinois	32-46	18-36	72-78	150-210	April 5-May 10	Oct. 5-Oct. 25
Missouri	32-50	34-38	76-80	170-210	March 25-April 25	Oct. 5-Oct. 30

the area. There is a marked tendency for the annual rainfall to increase from north to south and from west to east, within the region. Lowest average January temperatures are found in Minnesota whereas highest January temperatures occur in Missouri. The data indicate that in general the lowest

January temperatures prevail in the northern portion of the region and the highest January temperatures in the southern portion. Conversely, highest average July temperatures occur in the southern portion of the region and lowest average July temperatures in the northern portion. The average number of days without killing frost varies from 80 to 180 days in the northern portion of the region to 140 to 210 days in the southern portion.

Successful Establishment of New Seedings Essential

Germination and early stages of seedling development are critical periods in the life of small-seeded grasses and legumes in many portions of the north-central area. Seeding failures are costly and shortages of hay and pasture frequently result unless through added expense emergency hays and pastures are established. Among the more important practices which are recognized in reducing "seeding" hazards of small-seeded grasses and legumes are (1) liming and fertilizing with phosphate and potash, (2) preparing a firm, moderately smooth seed-bed, (3) shallow coverage of seed, (4) reducing competition from the companion (nurse) crop and from weeds, (5) proper inoculation of legumes, (6) use of adapted seed of good quality, (7) seeding at the right time, (8) mulching, (9) maintaining adequate reserves of organic matter in the soil, and (10) proper management of the seeding following establishment.

Adapted Varieties and Species

A considerable number of species are available for hay, pasturage, grass silage, green manure and for seed production in the north-central area. None of the species which are grown within the region is adapted to all of the soil and climatic conditions which prevail. The use for which the seeding is intended and the local adaptation of the species in the area or areas serve as the basis for devising seeding mixtures. The most important grasses and legumes for hay, green manure, pasturage, grass silage and seed production in the north-central area are as follows :—

Kentucky bluegrass (*Poa pratensis*).
Canada bluegrass (*Poa compressa*).
Timothy (*Phleum pratense*).
Smooth bromegrass (*Bromus inermis*).
Redtop (*Agrostis alba*).
Orchard grass (*Dactylis glomerata*).
Reed canary grass (*Phalaris arundinacea*).
Meadow fescue (*Festuca elatior*).
Sudan grass (*Sorghum vulgare* var. *sudanense*).
Alfalfa (*Medicago sativa*). Winter hardy varieties such as Grimm, Cossack, Ladak, Hardigan and Canadian Variegated are used in the northern portion of the region, whereas Common alfalfa is grown in the southern portion where winters are less severe. Ranger, Buffalo, Ladak or mixtures of Ladak and Cossack, or Cossack and Ranger are suggested in various portions of the region for soils infested with bacterial wilt disease (*Phytomonas insidiosa*).

Medium red clover (*Trifolium pratense*). Cumberland is recommended in the southern portion of the region whereas Midland is grown in the south-central portion. Seed from locally grown, hardy stocks have given best results in the States in the northern portion of the region.
Mammoth red clover (*Trifolium pratense perenne*).
Biennial sweet clover (*Melilotus alba* and *M. officinalis*).
White clover and ladino white clover (*Trifolium repens*).
Alsike clover (*Trifolium hybridum*).
Korean lespedeza (*Lespedeza stipulacea*).
Common lespedeza (*Lespedeza striata*).
Soybeans (*Soja max*).

Other species which are used for forage and green manure include the following :—

Rye (*Secale cereale*)
Oats (*Avena sativa*).
Barley (*Hordeum vulgare*).
Wheat (*Triticum vulgare*).
Corn (*Zea mays*).
Sorghum (*Sorghum vulgare*).
Millet (*Setaria italica* and *Panicum miliaceum*).
Red fescue (*Festuca rubra*).
Meadow foxtail (*Alopecurus pratensis*).
Italian ryegrass (*Lolium multiflorum*).
Rough-stalked meadow grass (*Poa trivialis*).
Cowpeas (*Vigna sinensis*).
Vetch (*Vicia villosa* and *V. sativa*).
Field peas (*Pisum arvense*).
Annual white sweet clover (*Melilotus alba* var. *annua*).
Crimson clover (*Trifolium incarnatum*).
Rape (*Brassica napus*).

Liming and Fertilizing

Applications of lime, phosphate and potash on the basis of soil and plant needs have become relatively common throughout the north-central area. Where needed, lime, phosphate and potash aid new seedings to survive drought, hot weather, grasshoppers and competition from the companion crop and weeds. Lime is often applied advantageously from 6 to 12 months in advance of sowing. Commercial fertilizers are usually added to the soil just prior to the time of seeding. General recommendations relative to the use of lime, phosphate, potash and manure for establishing seedings of the small-seeded grasses and legumes in the north-central area are given in Table 2.

Manuring

Most complete information relative to the use and value of barnyard manure in the establishment of small-seeded grasses and legumes in the north-central area is available from the Ohio Agricultural Experiment Station (Thatcher, Willard and Lewis, 1937). Studies made at this station indicate that manure may serve as a valuable adjunct in the establishment of new seedings especially on poor soils and soils low in organic matter. Yields of wheat which were top-dressed with manure in December at the rate of 4·5 tons per acre were increased 6 bushels per acre. The following crop of hay was 850 pounds greater per acre than that of an area which was not manured. In similar studies in eastern Ohio acre increases in yield of 9·7 bushels of wheat

TABLE 2

Recommendations relative to the Use of Lime, Commercial Fertilizer and Barnyard Manure in establishing New Seedings in the North-Central Area. (Acre basis.)

	Wisconsin	Minnesota	Iowa	Missouri	Illinois	Indiana	Michigan	Ohio
Lime	1-3 tons generally 4-6 tons on Spencer soils	According to soil tests, trials and experience	According to soil tests, trials and experience	According to soil tests, trials and experience	2-4 tons. More lime required for sweet clover than any other crop	According to soil tests, trials and experience	2-3 tons	According to soil tests, trials and experience
Barnyard manure	...	...	...	Moderate applications on infertile soils and soils low in organic matter	...	...	...	4 to 8 loads of straw or manure
Commercial fertilizer	200-400 lb. of 0-20-10 for silt and clay loams. 0-20-20 or 0-10-20 for sandy soils, and 0-9-27 or 0-8-32 for mucks, peats, and black bottom soils	According to soil tests, trials and experience	According to soil tests, trials and experience	200-500 lb. of 20% superphosphate 200-300 lb. of 4-16-4 or 4-12-4 on infertile soils low in organic matter. If barnyard manure is used only phosphate fertilizers are applied. Lespedeza can be established without fertilization but yields are increased by application of lime and phosphate	500-2000 lb. of rock phosphate or 100-300 lb. of 20% superphosphate 100-150 lb. of muriate of potash where needed	According to soil tests, trials and experience	500 lb. 20% superphosphate for establishing ladino clover. 300-500 lb. of 0-14-7 on heavy soils; 0-20-20 on medium soils; 0-9-27 or 0-8-24 on light soils. 300-500 lb. 20% S.P. for re-establishment of white clover in permanent pastures	100-400 lb. of 0-20-0, 0-14-7 or 0-12-12. Use of 0-20-0 is usually restricted to highly productive soils which receive heavy applications of barnyard manure. The higher rates of fertilization are suggested for longer rotations which include 2 or more years of meadow and when barnyard manure is not used. 350-400 lb. of 0-14-7 or 0-12-12 for establishing alfalfa by the trash mulch method.

and 1110 pounds of mixed hay were obtained following a broadcast application of 4·5 tons of manure per acre to the winter wheat in December. Studies in Ohio also indicate that manure may prove beneficial to new seedings when applied to the seed-bed and disced in, or applied in the summer as a top-dressing. Applications of manure at the time of seeding may have a tendency to increase the growth of straw of winter wheat in some seasons, with subsequent danger of lodging. Using the manure as a winter top-dressing reduces this hazard of lodging and at the same time benefits the grasses and legumes. The effect of top-dressing wheat with manure compared with plowing it under prior to seeding has also been studied by the Ohio Agricultural Experiment Station (Thatcher, Willard and Lewis, 1937). In this study applying manure as a winter top-dressing on the wheat increased the yield of clover hay about 0·5 ton when compared to plowing it down. When manure is applied as a top-dressing to new seedings the benefits which result are due in large part to the fact that the thin layer of manure not only adds nutrients but serves as a mulch to conserve soil moisture, provide coverage for the seed, protect the young seedlings from drying and soil blowing, reduce fluctuations in soil temperature, reduce soil losses from erosion and protect the seedlings from excessive heaving during the winter period.

Seed-Bed Preparation

Poor seed-bed preparation is responsible for many seeding failures in the north-central area. From information which is available in the region it is clear that a good seed-bed for small-seeded grasses and legumes should possess the following characteristics :—

1. There should be ample moisture in the surface soil and sub-soil.
2. The surface soil in which the seeds are to be sown should be reasonably smooth and granular but not fine or pulverized.
3. The soil should be firm beneath the depth to which the seeds are to be sown.
4. The plowed layer of soil should be in direct contact with the layer below to provide for an uninterrupted upward movement of soil moisture and nutrients.

While the importance of a good seed-bed must be recognized whenever new seedings of small-seeded grasses and legumes are to be made, greater care must be exercised in its preparation when seedings are made in the late spring and summer period than in early spring. In the early spring, moisture and temperature conditions are usually more favorable for rapid seedling emergence and establishment than in the more hazardous late spring or summer period.

Loose seed-beds dry out rapidly and the moisture which they contain is not readily available to the roots of seedling grasses and legumes. Where erosion is not a problem, fall plowing at moderate depths provides sufficient time for the soil to settle under conditions where seedings are made in the spring. Shallow plowing in the spring is preferred, otherwise the plowed layer will be too loose. Where discing or the use of a spring-tooth harrow

Fig. 52.—Ladino clover in combination with adapted grasses provides excellent forage on fertile

Fig. 53.—Hillsides such as this can be renovated with alfalfa, sweet clover and red clover, with little or no danger of soil loss by erosion.

Fig. 54.—A good seed-bed, prepared by scarification of the sod with a field cultivator, disc or spring-tooth, is necessary for successful establishment of legumes in worn-out pasture sods.

Fig. 55.—Sweet clover and red clover established in permanent bluegrass pastures by renovation assure the production of high quality nutritious forage, even during the dry midsummer period.

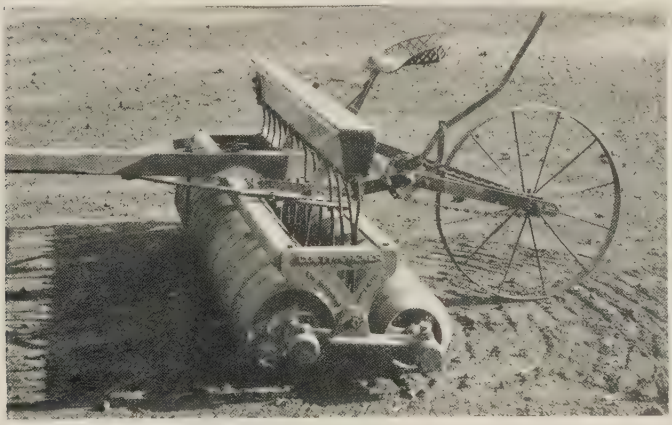

Fig. 56.—A cultipacker seeder saves seed by shallow coverage and by providing the soil with the desired firmness.

Fig. 57.—Sudan grass is used to advantage as a source of succulent, highly palatable forage during the midsummer period.

Fig. 58.—Bromegrass/alfalfa pastures such as this promote high milk production over a long pasture season.

is practical as the first step in preparing the seed-bed, the soil is left in the desired firm condition. A corrugated roller or cultipacker may be effectively utilized to crush coarse lumps and make the soil surface firm prior to seeding. Likewise, cultipacking following seeding is effective in packing moist soil around the seed. When late spring and summer seedings are to be made, the soil is worked prior to seeding in such a manner that a firm seed-bed is maintained and weeds are destroyed. For summer seedings discing is usually preferred to plowing in preparing the seed-bed.

Overworking the seed-bed on heavy soil may make it too loose. The surface layer can be reduced to a fine garden or dust-like tilth which may not be desirable. A heavy rain following seeding in such a seed-bed is occasionally followed by hot, dry weather. Crusts usually form on the soil surface under these conditions. Many of the seedlings are unable to emerge through the crust. A better stand will usually follow if the surface is somewhat granulated or lumpy because of the reduced danger of crusting and baking. On the other hand a very lumpy, coarse or trashy seed-bed requires heavier rates of seeding because of uneven distribution and covering of seed.

Renovation (Burson and Crim, 1943; Burcalow and Ahlgren, 1942; Graber, 1936; and Borst and Yoder, 1943) is based on establishing and maintaining heat- and drought-resisting legumes—sweet clover, alfalfa, red clover—in thin, unproductive sods on hilly, erodible lands without plowing. In this procedure, which is extensively used in Wisconsin and to a lesser extent in Minnesota, Iowa, Illinois and Ohio, the seed-bed is prepared by tearing up the sod thoroughly with a disc, spring-tooth or field cultivator. Thorough cultivation is essential since it is necessary to destroy most of the grassy vegetation and incorporate needed lime, phosphate and potash into the soil to assure the successful establishment of the legumes. Studies in Ohio (Borst and Yoder, 1943) have shown that the conversion of existing vegetation into a trashy surface mulch by discing promotes infiltration, decreases and controls runoff, eliminates erosion, and conserves moisture by decreasing surface evaporation. Such protection is not provided by plowing.

Depth of Seeding

Seeds of many of the common forages used for hay, pasturage, grass silage and green manure or for seed production in the north-central area are small. They do not have sufficient penetrating power and food reserves to emerge through 3 or 4 inches of soil. The importance of shallow seeding of small-seeded grasses and legumes has been clearly and conclusively demonstrated in field and greenhouse studies at the Ohio (Moore, 1943), Minnesota (Murphy and Arny, 1939), and Wisconsin (Ahlgren and Ream, 1937; and Wagner, 1943) Agricultural Experiment Stations. From a review of the data which is given in these studies it is clear that maximum seedling emergence of small-seeded grasses and legumes is usually obtained by planting at depths of 0·25 to 0·5 inch in heavy soils and 0·5 to 1 inch in sandy soils. Recent studies at the Wisconsin Experiment Station (Wagner, 1943) appear to warrant the conclusion that post-emergence damping off may increase in alfalfa, sweet clover and red clover as the depth of planting is increased.

Methods of Seeding

The most common method of seeding small-seeded grasses and legumes in the north-central area is by means of the "grass seeding attachment" used with a grain drill. The grain is drilled into the soil from 2 to 3 inches deep and the grass and legume seeds are distributed separately on the soil surface, on the sides and at the bottom of the furrows which are opened by the discs or shovels of the grain drill. When the companion crop is seeded 2 or 3 inches deep much of the seed of the forage grasses and legumes is covered too deeply. Those which drop in or near the bottom of the furrows are not likely to emerge from heavy soils. Extending the "grass seed" tubes so as to drop the seed behind the discs, or shovels, helps to insure shallower coverage on heavy soils. Such seedings should be harrowed lightly or rolled with a cultipacker or corrugated roller.

In addition to the "grass seeding attachment" on the grain drill, broadcasting by hand, broadcast seeders, wheelbarrow, cyclone and horn seeders, endgate seeders, clover-grass drills and cultipacker seeders are used in sowing small-seeded grasses and legumes. All of the methods of seeding provide satisfactory results if they are properly used. The cultipacker seeder was developed at the Wisconsin Agricultural Experiment Station (Ahlgren and Graber, 1940) and has been used successfully on sandy and heavy soils with the exception of red clays. The seed is dropped between the front and rear roller of the cultipacker. By using this method rates of seeding may be reduced by as much as 25 per cent and some of the work which is usually required in preparing the seed-bed is eliminated. If the field is level but lumpy the grain can be drilled in without further working of the soil since the rollers will crush the clumps sufficiently. On very heavy soils, such as red clays, the cultipacker seeder may not be satisfactory if the surface soil is moist and baking and crusting follow seeding.

The cultipacker seeder was developed as a result of the "cultipacker method" of seeding which has been used by farmers in many portions of the north-central area. Studies at the Minnesota and Ohio Agricultural Experiment Stations (Arny, 1924, and Thatcher, Willard and Lewis, 1937) have shown that this method is superior to any method which involves drilling the small-seeded grasses and legumes into the soil. When this method is used the seed-bed preparation is completed with cultipacking, after which the seed is broadcast on the soil surface. Much of the seed falls into the firm shallow furrows left by the cultipacker and is covered to a uniform shallow depth by cultipacking again or by a harrow or weeder on soils which crust badly following seeding.

Best results throughout the north-central area are usually obtained when the seed is applied in such a manner that it falls on the soil surface. When the seed is applied after the soil becomes dry enough to work, it must be covered uniformly and shallowly if uniform stands are to be obtained. Proper coverage is accomplished by harrowing lightly or by cultipacking.

For very early seeding in late winter or early spring, broadcasting is the only available means of applying the seed. Coverage of the seed is not essential when very early spring seedings are made because the surface of the

soil does not dry out rapidly at this time. Coverage of the seed, particularly in the northern portion of the region and in soils which are high in organic matter, is accomplished by the freezing and thawing action of the soil. Seeding small-seeded grasses and legumes in winter grain is frequently delayed until the soil is sufficiently dry to permit a drill (special grass seed drill or a grain drill with a grass seeding attachment) to be used. When the surface soil has dried out somewhat, drilling is superior to broadcasting (Thatcher, Willard and Lewis, 1937), but on soils which dry out slowly, very early broadcast seeding is usually superior to drilling because the seed can be broadcast earlier when conditions are more favorable for germination and there is less competition from the small grain companion crop.

Seed of bromegrass is large and light in weight. It will not pass through ordinary grass seeding equipment. The seed is broadcast by hand or mixed with the grain companion crop and seeded with the grain. The endgate seeder is used in Illinois (Fuelleman, 1941) and Missouri (Brown, 1942) for seeding bromegrass. Care must be taken to plant the bromegrass shallow when mixed with grain, not more than 1 to 1·5 inches deep. Studies in Michigan indicate that bromegrass may become established more rapidly if applied broadcast to the soil surface, after which it is covered by cultipacking.

Competition from the Companion Crop

Seventy-five per cent or more of grass and legume seedings in the north-central area are made in conjunction with a small grain companion crop. A companion crop is generally used when new seedings are made to (1) prevent soil erosion by wind and water while the relatively slow-growing grasses and legumes are becoming established, (2) control annual weeds, and (3) provide some return from the land during the first year of seeding. Recent studies in Ohio (Willard, etc., N.D.) also indicate that fall-sown companion crops may occasionally provide some protection to seedling legumes against injury from freezing when seedings are made very early in the spring.

Even under the most favorable conditions the companion crop competes directly with the new seeding for light, moisture and available soil nutrients. In general the best stands of grasses and legumes are obtained when the growth of the companion crop is not excessive.

As a rule satisfactory " catches " of small-seeded legumes and grasses are secured with a companion crop if this is managed in such a way that it does not compete too much with the seeding. In wet seasons and on fertile soils a tall growth of grain that lodges badly is almost sure to destroy the seeding unless it is cut for hay or silage immediately after it lodges. On heavy, fertile soil, thick growths of grain may shade the seeding and take so much moisture from the soil that in dry, hot summer weather the seeding may be destroyed. On sandy soils and soils low in organic matter the companion crop competes with the seeding even more, because it robs the latter not only of light but also of soil moisture.

On soils with a good water-holding capacity that have been properly limed and fertilized, early-maturing grains are harvested for grain, if they do not lodge, without endangering the seeding. In very dry years it may be necessary to clip or cut the grain for hay or to pasture it to prevent too great

loss of water on heavy, as well as light, sandy soils. Flax and canning peas have been found to be excellent companion crops for new seedings in areas within the region where they are adapted. Soybeans and Sudan grass are not dependable companion crops for small-seeded grasses and legumes.

The practice of sowing small-seeded grasses and legumes at the time of the last cultivation of corn has been investigated by the Ohio Agricultural Experiment Station (Willard, etc., N.D., and Thatcher, Willard and Lewis, 1937). Prolonged tests at this station indicate that this procedure of sowing is successful in about only two-thirds of the seasons. It is usually successful under Ohio conditions if seedings are made early (by July 4) and if 0·6 inches or more of rain follow seeding within a reasonable time. Results with this method of seeding have been most successful with alfalfa, common yellow sweet clover, Korean lespedeza, hairy vetch, English ryegrass and orchard grass. Seedings of red clover, alsike clover, common white sweet clover, crimson clover, ryegrass, soybeans, timothy, cowpeas and rape made at the time of the last cultivation of corn were generally inferior.

Studies in the north-central area indicate that excessive competition between the companion crop and new seedings can be reduced by :

1. Using stiff-strawed, early-maturing varieties of small grains.
2. Sowing spring varieties of small grains at one to two-thirds the usual rate.
3. Eliminating the companion crop entirely if seedings are to be made in late summer or early fall excepting under conditions where excessive erosion may occur, or to provide a seed mixture with sufficient weight to feed through a drill or endgate seeder.
4. Clipping the spring growth of grain at a height of 3 or 4 inches when the grain is 5 to 6 [Wisconsin (Ahlgren and Graber, 1940)] or 8 to 12 [Ohio (Willard, etc., N.D.)] inches tall. This treatment is suggested when the grain is grown on heavy soils and if seasonal growth indicates that lodging is likely to occur. The clippings are left on the field. With such treatment the small grain recovers but it will usually be much shorter and there will be less likelihood of lodging. Yields may be increased if lodging would otherwise have occurred, or they may be greatly reduced if clipping is followed by severe drought. In any event, the clipping treatment is a most valuable safeguard to the seeding.
5. Pasturing grain grown on heavy soils after it has reached a height of 10 to 14 inches. In general, results indicate that close grazing should be avoided. If the soil is not too soft, tramping by the livestock is helpful because this consolidates the soil and safeguards the plants from summer drought. If the grain recovers after grazing, it may be cut for hay when headed and in the dough stage. Under Missouri conditions (Etheridge, Helm and Brown, 1937) the grazing of winter wheat and winter barley is regulated according to the immediate need for pasture and the future need for threshed grain. If the greater need is for pasturage, the grain companion crops may be grazed out completely in April and May without injury to the new seeding.

Fall-sown companion crops are grazed moderately in April if a grain crop is desired.

6.* Cutting the grain for hay or silage shortly after serious lodging.

7.* Cutting the grain for hay or silage after heading whenever drought has been severe and where soils are moderately sandy, are lacking in organic matter and dry out rapidly.

8. Discing or harrowing of fall-sown rye in early spring to retard its initial growth and to prepare a seed-bed for spring seeding on sandy soils.

Competition from Weeds

Heavy or excessive growths of weeds may cause considerable injury to new seedings of small-seeded grasses and legumes Under certain conditions competition between weeds and the new seedings for light, moisture and soil nutrients may be even more severe than between excessive growths of the companion crop and new seedings. Many weeds thrive and grow rapidly even under conditions of limited fertility and low soil moisture. Species of weeds with broad leaves may cause extensive injury to new seedings because of excessive shading. While weeds cannot be eliminated entirely they can usually be effectively controlled so as to provide a minimum of competition to new seedings. Certain practices for reducing the hazards of weeds to new seedings have been suggested. They include :

1. Seeding as early in the spring as a good seed-bed can be prepared on soils which are not excessively weedy. Climatic conditions at this time are usually favorable for the prompt germination and rapid establishment of both the new seeding and the grain companion crop. The biennial and perennial forage crops grow at lower temperatures than many of the troublesome annual weeds so that early seeding gets them started ahead of the weeds.
2. Delaying seeding somewhat in favor of working the soil at weekly intervals if annual weeds are very troublesome. Many weeds are destroyed as they germinate and emerge, by this treatment.
3. Providing lime, phosphate and potash where needed for a vigorous growth of the seeding.
4. Avoiding seeding in soils which are badly infested with perennial weeds until such time as they have been eliminated by cultural procedures which are effective in their control.
5. Using forage seeds which are not contaminated with weed seed.
6. Sowing a fall or winter variety of grain in the spring at the time of seeding small-seeded grasses and legumes. Studies at the Ohio Agricultural Experiment Station (Thatcher, Willard and Lewis, 1937) have shown that winter wheat may be sown in the spring at the time of seeding small-seeded grasses and legumes. The wheat, which does not produce heads when sown in the spring, checks the

* Sweet clover is injured by the close cutting which is involved in removing the small grain for hay. It is not advisable to cut a companion crop in which sweet clover has been sown unless it is certain that the sweet clover would be destroyed in any case.

weed growth until the forage grasses and legumes are well established. Winter wheat seeded in the spring usually dies in mid-summer.

7. Delaying seeding until late summer or early fall. Seedings made during late summer or in early fall are established with a minimum of competition from weeds. Moreover, sufficient time is available before seeding for working the soil periodically to destroy troublesome and persistent weeds.
8. Mowing of heavy, rank growths of weeds to avoid excessive competition with the new seeding. Studies in Ohio (Thatcher, Willard and Lewis, 1937) indicate that the weeds are most effectively controlled when they are permitted to make as much growth as is consistent with saving the stand of forage before they are mowed. With such treatment the weeds will die when they are cut and the small-seeded grasses and legumes will make a maximum of top and root growth. A tall, dense growth of weeds is more likely to be destroyed than a short, open one, since in the former the buds on the weed stubble have been destroyed by shading. Weedy fields of seedings including alfalfa, red clover and alsike clover may be cut closely without destroying the legumes. Seedings of sweet clover are cut high, otherwise the plants may be destroyed.

Inoculation of Legumes

Only leguminous plants which have nodules on their roots have the capacity to fix nitrogen. Bacteria within the various cross inoculation groups vary considerably in their ability to fix atmospheric nitrogen in association with the host leguminous plant even though nodules are formed. Some strains have been found which fix little nitrogen whereas others fix considerable quantities. Moreover, many strains found in soil in which legumes have been grown previously are lacking in ability to fix appreciable quantities of nitrogen. Cultures of proper inoculation of all the important cultivated leguminous plants which are grown in the north-central area are available commercially. Because of the tremendous benefits which result, their use is suggested whenever legumes are sown. Proper inoculation is not only an effective means of safeguarding the small-seeded legumes against the hazards of the environment and of increasing yields, but it is the cheapest possible means of increasing the nitrogen supply of the soil.

Time of Seeding

In general new seedings which include legumes are made as early in the spring as a good seed-bed can be prepared. Early seeding promotes prompt germination and good rooting of the young plants before the warm dry period. Late May or June seedings are usually not satisfactory. When seedings are made at this time they may not become sufficiently well established to withstand the hazards of summer heat and drought. Furthermore, yields of the grain companion crop will usually be low.

On heavier soils, alfalfa and sweet clover may be seeded in early summer if grasshoppers are not numerous. Alsike clover, red clover, white clover and

the grasses are not seeded during the warmest portion of the summer period. Alfalfa or sweet clover may be seeded in July whenever moisture conditions are favorable for the rapid germination of the seed and subsequent establishment of the plants. Legume seedings made after the middle of August may not make sufficient growth to overwinter in most portions of the north-central region. If sown after mid-August, mixtures of grasses and legumes are more likely to survive than legumes alone. The grasses afford some protection to the seedling legumes against winterkilling and heaving in the late winter or early spring. Mulching with 4 to 5 tons of manure or 1 ton of straw per acre immediately following seeding during the summer period has resulted in marked improvement in stands of legumes under Ohio conditions (Thatcher, Willard and Lewis, 1937).

Fall seedings of grasses are often more successful than spring seedings. Dates for making fall seedings vary from August 15 to September 10 in the northern portion of the region and August 20 to October 15 in the southern portion. Orchard grass is seeded in the spring rather than in the fall excepting in the extreme southern portion of the region where fall seedings can be made. When grasses are seeded in the fall, legumes are either broadcast on the surface in late winter or very early in the spring, or they are drilled in as soon as the soil becomes dry and firm enough to permit the use of machinery on the land.

At times certain grasses and legumes are sown in late fall or in the winter. Reed canary grass, sown just before the soil freezes, will remain viable in the soil and begin growth as soon as conditions are favorable in the spring. Late seedings of unhulled sweet clover made in November, December, January and February have proven satisfactory. Lespedeza may be seeded at any time during the period December to March, inclusive (Etheridge, Helm and Brown, 1937, and Brown, 1941).

Late winter or very early spring seedings of legumes may be subject to freezing hazards. Seeds sown at this time are covered by the freezing and thawing action of the soil or by rain which washes soil over the seeds. The moist condition of the soil assures germination as soon as temperature conditions become favorable for growth. Subsequent freezing may, however, destroy many of the germinating seedlings. The Ohio Agricultural Experiment Station (Thatcher, Willard and Lewis, 1937) has suggested "split seedings" as a means of offsetting the hazard of freezing when very early seedings are made. When this procedure is used, one half of the seed is applied broadcast early (March 1 to March 15) and the remaining half 2 to 3 weeks later, either broadcast or with a drill.

Mulching

Information relative to the value of mulching as a means of obtaining good stands of small-seeded grasses and legumes in the north-central area is limited to studies conducted at the Ohio Agricultural Experiment Station (Moore, 1943; Willard, etc., n.d., and Thatcher, Willard and Lewis, 1937). Data given in Table 3 are illustrative of results which have been obtained in mulching studies under Ohio conditions (Moore, 1943). In these studies a straw mulch was applied to the soil surface at the rate of 1 ton per acre.

Data in Table 3 indicate that the straw mulch proved favorable to seedling emergence. The beneficial effect of the mulch in these studies is attributed to (1) higher and less variable moisture content of the soil surface, (2) lower maximum temperature, and (3) less compaction by rainstorms. In other studies in Ohio (Willard, etc., N.D., and Thatcher, Willard and Lewis, 1937) it has been observed that mulches provide young seedlings with excellent

TABLE 3

Emergence of Seedlings from Various Soil Depths under Field Conditions on Miami Silt Loam Soil at Columbus, Ohio

(Seeded May 18, 19, 20, 1939)

Species	Percentage of viable seeds that produced emerged seedlings by the 25th day after planting at the depth indicated											
	Seed-bed bare						Seed-bed mulched					
	0 in.	¼ in.	½ in.	1 in.	1½ in.	2 in.	0 in.	¼ in.	½ in.	1 in.	1½ in.	2 in.
Alfalfa	42	75	63	48	7	1	76	85	82	73	45	16
Yellow sweet clover	35	44	43	30	6	2	53	78	78	73	36	12
White sweet clover	15	34	30	15	2	0	49	60	62	42	15	5
Red clover	40	45	39	25	1	1	74	85	86	70	26	3
Alsike clover	39	21	22	7	0	0	70	91	91	46	7	1
Crimson clover	57	83	78	50	9	0	78	95	93	75	45	5
Korean lespedeza	48	88	82	33	3	0	70	96	92	66	9	1
Orchard grass	37	58	59	41	9	3	44	95	86	69	36	10
Timothy	30	46	27	3	0	0	49	70	68	23	1	0
Sudan grass	32	65	78	75	72	72	37	80	74	84	75	67

winter protection against cold and freezing and thawing. Mulching wheat during the fall or winter with straw or other residues low in nitrogen often reduces the growth and yield of the wheat because of the resulting decrease in the amount of available nitrogen in the soil. This reduced growth of the wheat favors the stand of small-seeded grasses and legumes, especially under conditions where a rank growth of straw may be produced.

Applications of straw at the rate of 1 to 1·5 tons per acre or manure at the rate of 4 to 6 tons per acre are recommended by the Ohio Agricultural Experiment Station (Willard, etc., N.D., and Thatcher, Willard and Lewis, 1937), when seedings of small-seeded grasses and legumes are made in the summer. In addition to conserving moisture, such mulching prevents crusting, retards drying, reduces the temperature of the soil, reduces soil losses by erosion and protects the young seedlings against heaving injury during late winter or early spring.

ORGANIC MATTER NEEDED IN THE SOIL

The increasing number of seeding failures in certain portions of the north-central area have been attributed in part to a gradual decrease in the organic matter content of the soil. Studies at the Wisconsin Agricultural Experiment

Station (Ahlgren and Ream, 1937) (Table 4) show that stands of small-seeded grasses and legumes planted at various depths in Miami silt loam soil (low in organic matter) were significantly inferior to stands obtained when plantings were made in Carrington silt loam soil (high in organic matter). In general, losses by erosion are greater when the soil is low in organic matter. The water-holding capacity of such soils is low and baking and crusting are more

TABLE 4

Effect of Depth of Planting and Type of Soil on Emergence of Small-seeded Grasses and Legumes

(Greenhouse studies—Wisconsin, 1937)

Species	Depth of planting in inches									
	Miami silt loam					Carrington silt loam				
	0 in.	½ in.	1 in.	1½ in.	2 in.	0 in.	½ in.	1 in.	1½ in.	2 in.
Kentucky bluegrass	42	61	28	0·3	0·1	64	68	43	6	0·9
Timothy	58	91	55	7	0·9	93	93	84	40	13
Redtop	68	66	25	0·2	0	74	73	36	3	0·3
Red clover	0	19	16	2·3	2·3	68	64	68	23	13
White clover	18	33	8·4	0	0	81	81	45	3	0
Alsike clover	4·6	26	5·7	0	0	57	63	57	10	4
Alfalfa	9·6	58	72	58	16	80	76	68	52	24
Common sweet clover	9	35	46	34	2·7	62	62	55	34	14
Smooth bromegrass	18	87·5	80	61·5	40	70	80	75	60	35

common. Greater care is needed in preparing the seed-bed. Seeding as early as possible and careful management of the nurse crop are necessary.

Practices which result in increasing the organic matter content of soils which are low in such substance are recommended throughout the region. Rotations which emphasize the greater use of forages and green manure crops are excellent means for this purpose.

MANAGEMENT DURING YEAR OF SEEDING

Most new seedings of grasses and legumes are made in conjunction with a small grain companion crop. Under some conditions (which have been previously discussed) it is highly desirable to graze, clip or mow the companion crop to reduce excessive and harmful competition between the companion crop and the new seeding. As a rule the new seeding, when grown with a companion crop, does not produce a heavy growth of forage during the year of seeding. Heavy grazing during midsummer or in the fall may result in considerable injury to the seeding. In general, excepting under unusually favorable conditions, best results are obtained if new seedings are not grazed heavily or mowed (excepting as necessary to control weeds) after the small grain crop has been removed. If sufficient growth is available, new seedings may be grazed moderately in July or August without subsequent injury to the

stand. Grazing is usually withheld in September and October. Seedings made in mid-summer or in the fall should not be grazed or mowed until the following year.

Studies conducted at the Ohio Agricultural Experiment Station (Vandermeulen, 1943; Willard, 1927; and Thatcher, Willard and Lewis, 1937) have shown that new seedings of alfalfa, alsike clover and red clover may be clipped to destroy weeds and remove the grain stubble without injury to the seeding if the clipping is done before the first of September. Weeds and stubble are removed by such treatment with resulting cleaner, better quality hay the following year. Studies in Ohio (Willard, 1927) have shown that sweet clover is injured by clipping or mowing during the year of seeding. Clipping is not recommended in August unless such treatment is essential to destroy vigorous, competing weed growth. The Ohio studies indicate that cutting sweet clover for hay during the first year is practical only when the value of the hay (on the basis of individual need) exceeds the value as green manure or pasturage the following year.

Red clover may blossom and produce seed during the first year when seasonal conditions are favorable. The opinion is commonly held by farmers in certain portions of the region that red clover which is permitted to produce seed during the first year will die. This view is not supported by observations at the Ohio Agricultural Experiment Station (Thatcher, Willard and Lewis, 1937) where heavy hay crops have been obtained in fields from which as much as 2 bushels of seed had been harvested the preceding fall. Cutting new seedings of red clover after September 1 may result in injury to the red clover because of the resulting lack of a suitable winter cover.

Small-seeded grasses and legumes grow slowly at first. During early stages of development they are poorly equipped to compete with weeds, with other rapidly growing species or with species which have been established previously. For this reason best results are usually obtained when seedings are made in a well-prepared seed-bed which is free of weeds. Occasionally, however, seedings of small-seeded legumes may be successfully established in the sod of permanent grasslands without preparing a seed-bed. Grazing techniques, designed to promote the establishment of sweet clover, red clover, lespedeza and white clover, have been developed in various portions of the north-central area. These grazing techniques are based on the recognized need of reducing excessive and harmful competition between the grassy components of the sward and the seedling legumes during their early stages of development. Grazing techniques which have been successfully used in establishing the above-mentioned legumes in permanent pastures are described below:

1. *Sweet clover and red clover.* The initial seedings of sweet clover and red clover are made in a well-prepared seed-bed. However, the duration of the beneficial effect of renovation is dependent to a considerable extent on the success which is attained in re-establishing the sweet clover and red clover in bluegrass sod from natural seedings. The following procedure has been developed by the Wisconsin Agricultural Experiment Station (Ahlgren, Wall, Muckenhirn and Burcalow, 1944) for re-establishing stands of sweet clover and red clover from natural seedings in bluegrass sods.

(*a*) After ample seed production is assured during years in which sweet clover and red clover normally produce seed (second year of growth), the pastures are grazed closely for the remainder of the growing period. The Kentucky bluegrass is weakened considerably by this treatment and the legume seeds are trampled into the soil by the cattle.

(*b*) During the following year the pastures are grazed closely very early in the spring when the sweet clover and red clover seedlings are still very small. This close grazing in early spring serves to reduce further the competition of the Kentucky bluegrass.

(*c*) If the Kentucky bluegrass recovers from the first grazing to the extent that a 4 to 5-inch growth is produced by the middle of June, the pastures are grazed again to reduce shading of the legumes. The pastures are grazed in such a manner that the growth of Kentucky bluegrass is reduced to the level of the legume seedlings, after which the cattle are removed.

(*d*) Moderate grazing may be practiced in July and August and occasionally in late fall after growth has been retarded by frost and cool weather. In general, however, best results are obtained if grazing is withheld in September and October.

2. *Lespedeza.* Korean lespedeza is grown more extensively than any other legume in Missouri. Studies in Missouri (Etheridge, Helm and Brown, 1937, and Brown, 1941) indicate that when lespedeza is grown in permanent pastures it can be maintained indefinitely by natural reseeding provided proper grazing management is practiced. Permanent pastures in which lespedeza is grown are grazed moderately hard in April, May and June. Moderately heavy grazing is suggested throughout this period to reduce the competition between the grass and the young lespedeza seedlings. The pastures are protected from grazing during most of July and August to permit the lespedeza to make a strong, vigorous growth. The pastures are grazed moderately in late August and September and are protected from grazing in October and November to give the grass an opportunity to replenish reserves which were depleted during the period of heavy spring grazing. The accumulated fall growth is grazed without injury to the plants after growth has been retarded or stopped by frost and cool weather.

3. *White clover.* Experimental and demonstrational studies in Michigan (Vandermeulen, McIntyre and Harrison, 1942) indicate that proper management accompanied by appropriate top-dressing with phosphatic fertilizer will result in the re-establishment of white clover in permanent pastures in areas in which this legume is adapted. Following the application of phosphate, white clover is established without seeding and maintained by continuous and close grazing. Studies in Ohio (Dodd, 1941) have shown that seasonal climatic conditions are of major importance in affecting the occurrence, fluctuation and distribution of white clover in lawns and pastures. During excessively dry seasons white clover disappeared from lawns and pastures in spite of the fertility and managerial treatments given to these areas.

Mixtures in North-Central Area

Kentucky bluegrass, Canada bluegrass, redtop, timothy, smooth bromegrass, alfalfa, red clover, alsike clover, white clover and biennial sweet clover occur generally throughout the region. Smooth bromegrass is more commonly grown in the western portion of the region, whereas white clover and Ladino clover are found in greater abundance in the eastern portion. Timothy is replaced by orchard grass to a certain extent in the southern portions of Ohio, Indiana, Illinois and Missouri. Orchard grass, Korean and common lespedeza are grown extensively for hay, and pasturage and seed only in the southern portion. The use of meadow fescue is restricted primarily to the western portion. Reed canary grass is grown on low, wet soils which are subject to periodic overflowing, particularly in the northern portion of the region.

Mixtures containing grasses and legumes are commonly sown throughout the area. The seeding mixtures vary according to the purpose for which they are intended and the soil and climatic conditions prevailing in the locality in which they are to be grown. Mixtures of grasses and legumes which are suggested in the various States comprising the region are generally simple, including only 2 or 3 species excepting in Illinois, where more complex mixtures comprising 4 or more species are frequently recommended.

Regardless of the seeding mixture to be used, the species which comprise the initial seeding are eventually replaced by other species, even though they are not included in the original seeding mixture. Kentucky bluegrass eventually becomes the dominant species on fertile, upland soils in almost all portions of the region, whereas on relatively infertile upland soils the species which are sown are replaced by Canada bluegrass. Vegetation of impoverished upland soils particularly in the eastern portion of the region reverts eventually to broomsedge (*Andropogon virginicus*) and poverty grass (*Danthonia spicata*). Species sown on wet, poorly drained soils are gradually replaced by redtop. Reed canary grass, provided it is established in soils to which it is adapted, is capable of resisting the invasion of all other species.

The following are illustrative of some of the types of mixtures used in the north-central area. They comprise only a few of the many which are recommended. All rates are quoted in pounds per acre.

I. Minnesota

A. Rotation pastures

(a) *Western section*		(b) *Eastern section*	
1. Biennial sweet clover	10	1. Red clover	4
Timothy or meadow fescue	6	Alsike clover	2
2. Ladak alfalfa	6	Timothy or meadow fescue	6
Smooth bromegrass	8	2. Ladak alfalfa	6
3. Ladak alfalfa	6	Smooth bromegrass	8
Smooth bromegrass	4	3. Biennial sweet clover	10
Meadow fescue	4	Timothy	6

B. Permanent pastures

(*a*) Add one pound of Kentucky bluegrass to the rotation pasture mixtures in the western section and one pound each of Kentucky bluegrass and white clover to the rotation pasture mixtures in the eastern section.

II. Missouri

A. *Permanent pasture on fertile well-drained soils*

Kentucky bluegrass	10
Timothy	5
Biennial sweet clover or Korean lespedeza	10

B. *Permanent pasture on well-drained soils of medium fertility*

Orchard grass	10 to 14
Redtop or Canada bluegrass	1 ,, 5
Korean lespedeza	10

C. *Permanent pasture on well-drained soils low in fertility*

Redtop	10
Canada bluegrass	1 to 3
Korean lespedeza	10

III. Wisconsin

A. *Permanent pasture on erodible (non-plowable) upland soil (established by renovation)*

Biennial sweet clover	12 to 15
Red clover	5
Timothy	2 ,, 3

B. *Soils suited to alfalfa and red clover*

1. Red clover	8
Timothy	6
2. Alfalfa	8 to 10
Timothy	2 ,, 4
3. Alfalfa	8 ,, 10
Smooth bromegrass	6 ,, 10

C. *Soils not suited to alfalfa and red clover*

1. Timothy	6
Alsike clover	4 to 6

IV. Illinois

A. *Fertile well-drained soils*

1. Timothy	6
Kentucky bluegrass	7
Red clover	3
White clover	2
2. Timothy	3
Smooth bromegrass	4
Kentucky bluegrass	4
Redtop	3
Red clover	2
Alfalfa	2
White clover	2
Alsike clover	2
3. Alfalfa	6 to 8
Smooth bromegrass	9 ,, 10

B. *Fertile poorly-drained soils*

Timothy	4
Meadow fescue	5
Redtop	3
Canada bluegrass	4
Alsike clover	2
White clover	2

C. *Infertile well-drained soils*

Orchard grass	5
Redtop	4
Canada bluegrass	5
Alsike clover	2
Korean lespedeza	5

D. *Infertile, poorly-drained soils*

Timothy	5
Redtop	5
Canada bluegrass	6
Alsike clover	3

V. Michigan

A. *Hay and/or pasture*

1. Ladino clover 4
2. Alfalfa 8
   Smooth bromegrass . . . 5 to 7
3. Alfalfa 5
   Red clover 3
   Alsike clover 2
   Timothy 2

B. *Permanent grass cover for orchards*

1. Fertile, loam soils—
   Kentucky bluegrass . 15
   Timothy 5

VI. Ohio

A. *Mixtures primarily for hay*

1. Alfalfa 6
   Red clover . . . 4
   Timothy . . . . 3 to 6
2. Alfalfa 4
   Red clover . . . 4
   Alsike clover . . . 2
   Timothy . . . . 3 „ 6
3. Alfalfa 10
   Orchard grass . . . 5 „ 8
4. Alfalfa 10
   Smooth bromegrass . . 5 to 10
5. Red clover . . . . 6 „ 10
   Timothy . . . . 3 „ 6
6. Red clover . . . . 4 „ 8
   Alsike clover . . . 2 „ 4
   Timothy . . . . 3 „ 6

B. *Mixtures primarily for pasture*

1. Add 3 to 5 pounds of Kentucky bluegrass and ½ to 1 pound each of Ladino and Louisiana white clover to any of the hay mixtures above adapted to the same situation.
2. Korean lespedeza 15
   Orchard grass 8
3. Biennial sweet clover 10
   Orchard grass . . . . . 5 to 8

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Central and Southern Great Plains *

Conditions and Problems

The Central and Southern Great Plains represent one of the largest and potentially important pastoral and agrarian regions in North America. The area includes most of the western halves of Kansas, Oklahoma and Texas and extends westwards through New Mexico and Colorado to the foothills of the Rocky Mountains. The highly variable but dominantly semi-arid climate, with intense heat during the summers and subzero temperatures in the winters, differs widely from that prevailing in other major regions of the world.

The average annual precipitation varies from 20 inches or more near the subhumid region east of the area to 17 inches in the west and 10 inches or less near the desert region in the Southwest. Two-thirds to three-fourths of the annual precipitation falls during the growing season, but its effectiveness is curtailed by hot weather and high winds and by the fact that much of it occurs in the form of torrential rains or light showers. Wind velocities which reach a peak in late winter and early spring are throughout the year usually higher than elsewhere in the continental interior. Every phase of the climate is highly variable from month to month and year to year. Severe droughts occur periodically throughout the entire region and alternate sporadically with favorable conditions across the area nearly every season.

The great drought of the thirties emphasized the fallacy of straight wheat production as commonly practiced in the region, sensationally demonstrated the tragic mistake made in plowing vast areas of stable grassland, and sharply focused public attention upon the critical need for adopting a more diversified and permanently self-sustaining system of agriculture with emphasis on grass, forage and livestock. The recent cooperative work of State and Federal research and action agencies is rapidly providing factual information basically necessary in effecting the desired change to a permanently successful system of grassland agriculture.

The substantial contribution of grass research to the current war effort through helping to give immediate and permanent stability to agriculture in the region is becoming increasingly evident in the extensive use of practices for the expansion and improvement of grasslands on farms and ranches throughout the area. The general public is adopting many diversified practices and is gradually correcting difficulties that arose as a result of the cataclysmic drought that followed wholesale plowing of grasslands during the last war. Much cultivated land in the region is now being restored to excellent stands of highly palatable and nutritious grasses. Superior strains of grass are being developed for this purpose. Vast areas of native range land are being improved and maintained in productive condition. Grass and related forage investigations

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conducted on a limited scale in the past and more extensively in recent years have provided the basic facts responsible for these material evidences of progress.

A major current concern of experienced plainsmen is the possibility that the serious mistake made in destroying millions of acres of productive grassland during the First World War will be repeated under the erroneous assumption that total food production will be thereby increased. It is a clearly established fact, but unfortunately not a fully appreciated one, that current and future food requirements can be met more adequately and in a sounder economic manner in this region by making every feasible effort to obtain maximum crop yields from the better cultivated land and by continuing to retire the less fertile and more erosive soils to grass, forage crops and livestock production. The Plains can effectively make substantial contributions to both the bread and meat baskets of the nation, but cannot long survive without disastrous results in again devoting its entire resources to the production of cereals alone.

Most soils of the Great Plains are high in fertility and consequently seldom respond with increased yields from fertilization unless the treatment is accompanied by irrigation. Many years of cultivation, however, has destroyed much of the original structure of the soil and impaired its general physical condition. Moreover, some soils already show evidences of reduced fertility and others are probably declining as a result of continued cultivation in disregard of soil preservation. These conditions indicate the importance of using grass and other herbage plants not only for the permanent retirement of submarginal land but also for use in rotations to improve the water-holding and wind-resisting qualities of the soil and to increase the production of cultivated crops and livestock products. Some progress is being made in returning the less productive cultivated lands to permanent pasture. Farmers, however, have not yet adopted the use of perennial grasses in rotation with cultivated crops, although the value of the practice is being determined and demonstrated by research agencies in the region.

Temporary Pasture Crops

Crops commonly grown for temporary pasture in the Central and Southern Great Plains are not suitable for use in mixtures in the region and are therefore grown only in pure stands. Chief among these are Sudan grass (*Sorghum vulgare* var. *sudanense*), winter wheat (*Triticum aestivum*), and biennial sweet clover (*Melilotus* spp.). These crops, together with the grain and forage sorghums (*Sorghum vulgare*), native hay and pasture grasses, a limited amount of alfalfa hay (*Medicago* spp.) and cottonseed cake, constitute the principal livestock feeds of the region.

The temporary pasture crops can be grown in a cropping system that provides opportunities for maximum production of green herbage throughout most of the year. This goal can be most nearly attained by growing sweet clover in rotation with Sudan grass and supplementing this sequence with wheat pasture during the winter months. The rotation requires one field for the Sudan grass and one each for the first and second-year sweet clover. The sweet clover is drilled alone early in the spring in the protective stubble and firm seed-bed left by the previous crop of Sudan grass. The Sudan grass is drilled in May on second-year sweet clover land that has been kept in a fallow

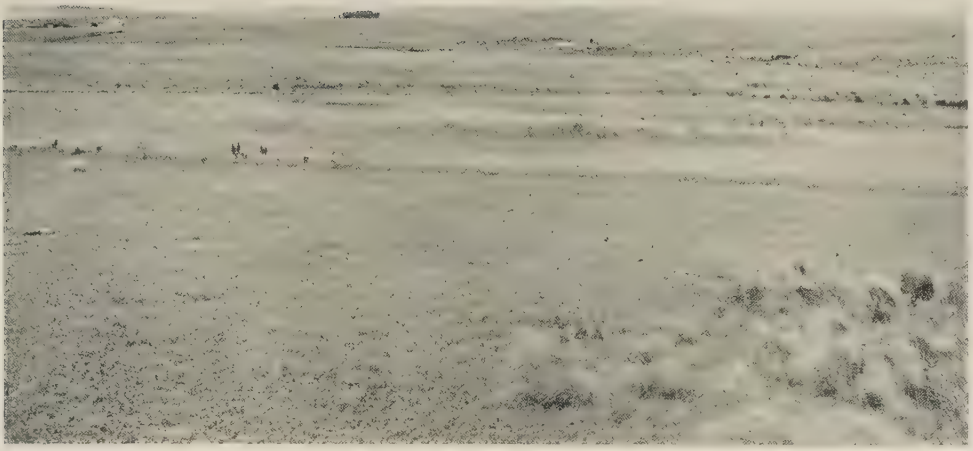

Fig. 59.—Native range of buffalo and blue grama grasses in the Southern Great Plains.

Fig. 60.—Blue grama grass range in the Southern Great Plains.

Fig. 61.—Sagebrush association on the rolling plains.

Figs. 62 and 63.—Conditions in the Dust Bowl after the great drought of the 1930's.

condition since the clover ceased production the previous year. This represents a fairly ideal sequence and preparation for both crops and insures maximum production in favorable seasons.

The second-year sweet clover usually supports heavy grazing from early spring until the Sudan grass is ready to be grazed in June. The Sudan grass, promoted by moisture stored during the preparatory fallow period, gives excellent yields of green herbage until heavy frosts occur in the fall. Winter wheat grown in the usual manner for commercial grain production often provides ample supplies of green pasturage during the fall, winter and early spring, but it cannot be depended upon to do this consistently and the livestock usually have to be removed by April 1 to insure grain development. For these reasons it is a safer and more dependable practice to set aside one field of wheat to be used for pasture purposes only. In this case the wheat is sown early in the fall on fallow land, grazed all winter, and plowed up for another fallow period as soon as the sweet clover is ready to be used in the spring.

These temporary pasture crops, when grown and utilized as indicated and supplemented with native range grasses, provide a dependable source of green herbage throughout most of the year. The grazable period of one crop usually overlaps with that of another in the rotational grazing system. First-year sweet clover and winter wheat can be grazed when the growth of Sudan grass diminishes in the fall. The native range grasses can be grazed when any of the other pasture crops fail to produce adequate forage.

Permanent Grass Mixtures

Lack of an adapted legume

The semi-arid climate frequently characteristic of the Central and Southern Great Plains is usually too adverse to support a legume in mixtures with permanent grasses. Many native and introduced legumes have been tested in a vain effort to discover a legume fully adapted for this purpose. Alfalfa fails to persist in grass mixtures except occasionally on especially favorable sites in the subhumid eastern fringe of the region or in the few irrigated valleys of the area. Lespedezas thrive only in the subhumid region to the east where the annual precipitation approaches or exceeds 30 inches. Sweet clover offers some possibilities, but a good stand of this legume often competes to the serious detriment of seedling grasses and usually fails to reseed itself. The result is that sweet clover/grass mixtures usually end in thin final stands of both crops. In a few instances where sweet clover and grasses have been established successfully in mixtures with each other, the legume has exerted a noticeable beneficial effect on the vigor and color of the associated grasses. Preliminary studies indicate that sweet clover might be used advantageously in improving infertile soils before proceeding to establish permanent grasses.

Manchurian milk vetch (*Astragalus cicer*) shows more promise than any other perennial legume thus far tested in the region but lacks the drought resistance of native grasses. Therefore, its use is likely to be restricted to the more favorable sites.

Much more intensive testing, propagation and improvement work should be done among the native legumes of the region. The possibilities have been

explored to a limited extent and without much success. The importance of the problem, however, fully justifies further and more intensive efforts. Most of the native legumes thinly scattered over the region are lacking in palatability and many of them possess toxic or poisonous properties. Native legumes which have been eaten safely and in varying degrees by livestock include *Cracca virginiana*, *Indigofera leptosepala*, and *Chamaecrista fasciculata*.

Superlative qualities of native grasses

The principal native grasses of the Great Plains region possess a combination of superlative characters which compensate in a large degree for the lack of an adapted legume to use with them. These grasses represent over 90 per cent of the range forage of the area and have desirable characters which in the aggregate are believed to be superior to those of any other combination of herbage in the world. They are extremely palatable and highly nutritious at all stages of growth and retain much of these values when fully dormant. They are usually much higher in essential food elements at all seasons in the year than are the grasses of humid, subhumid or mountainous regions. The protein content of the green herbage, for example, often exceeds that of excellent quality alfalfa hay and when this element is at its lowest ebb in these grasses it often equals or excels the highest protein content of subhumid grasses.

These grasses are also superlative in their combined resistance to intense heat, severe drought, subzero temperatures, heavy trampling, excessive grazing, soil blowing, water erosion, plant diseases and competition. They recover rapidly from the effects of excessive use, adverse climatic conditions and other abuses, produce much more forage than their stature indicates, are extremely long-lived, and form a dense soil-binding turf admirably suited for erosion control, landscaping purposes and airport stabilization. The surprisingly deep and highly ramified root systems of these grasses exert a prompt and beneficial effect on the structure of cultivated soils, which is retained long after they are plowed. The herbage usually yields more net returns in the form of livestock products than is commonly realized and often more than is obtainable from cultivated crops.

Establishing Permanent Grasses

Establishing excellent stands of native grasses on formerly cultivated land is no longer the difficult task it was several years ago before satisfactory methods of harvesting and seeding them were developed. Seed supplies are still a limiting factor, although increasing quantities of viable seed of several grasses are being harvested from native stands each year and the planting of other species solely for seed production is gradually expanding. Mixtures of the better species may be established most successfully by drilling them medium early in the spring in the undisturbed stubble and hay residue left by a previous crop of close-drilled sorghum. This standard method and alternative procedures are discussed in detail as follows.

Land preparation and stabilization

The ideal condition for seeding perennial grasses in the semi-arid districts of the Central and Southern Great Plains, where soil blowing and rapid surface

drying usually preclude the use of fallow land or clean-tilled crop land, is a fine, firm seed-bed, free of weeds and other competitive plants, containing sufficient moisture for germination and seedling development, and protected by high, dense stubble and crop residue to control runoff and wind and water erosion, reduce surface evaporation and prevent crusting. Sudan grass or any adapted variety of sorghum is best suited to provide these conditions. The protective mulch can be grown much cheaper than it can be applied artificially.

A suitable preparatory cover crop can usually be established on most cultivated fields with a minimum of tillage operations if adjacent areas are properly stabilized. Land for the preparatory crop is usually prepared by a fairly deep operation with a lister, plow, or one-way disk early in April and followed with sufficient tillage to destroy weeds and keep the soil in a rough condition receptive to moisture and conducive to the control of wind erosion.

The preparatory crop of sorghum is seeded in close drills in early summer at rates locally considered optimal for producing hay. Under favorable conditions good stands of grass may be obtained by drilling the following spring in the stubble left by removing the preparatory crop for hay or pasturage. Greater chances for success are afforded, however, by cutting the preparatory crop to prevent it from maturing seed, leaving a high stubble and all the hay on the land.

Wheat stubble fields may be used as seed-beds for grass in the northern part of the region and at high elevations farther south where winter-growing grasses are adapted and seeded in the fall. Such fields, however, usually represent poor seed-beds for spring seedings of summer-growing grasses best adapted to the region as a whole. Stubble fields of this kind usually become very weedy and infested with volunteer wheat by the following spring. Attempts to kill these plants often destroys the protective stubble and leaves the seed-bed undesirably soft and loose. The seed-bed may be firmed by packing but this encourages soil blowing.

Clean tilled, fine, firm seed-beds may be used successfully in the extreme eastern part of the region and in special locations throughout the area where the soils and protective features of the surroundings are such as to prevent wind erosion. The method is so susceptible to wind action and rapid surface evaporation, however, that it can rarely be used successfully in windier parts of the region where the protection of young seedlings from the drying and cutting action of the wind is of paramount importance.

Fertilizers are not recommended for most soils of the region because they are already noticeably high in essential food elements. Limited amounts of nitrogenous fertilizers might be used on the poorer soils, but care must be exercised to avoid the burning effect of heavy application during dry weather.

Time of seeding grasses

Most grasses best adapted to the region respond better to seeding in late March or early April than at any other time in the year, especially when the seedings must be made in protective cover before weeds emerge and without tillage in advance. In areas not susceptible to serious wind erosion where clean-tilled seed-beds are usable, it is possible to delay the seeding until late in April or May and thereby to destroy one or two crops of weeds before

planting. Most of the better grasses of the region seldom succeed when sown in the fall, because they develop extremely slow in cool weather, enter dormancy early in the fall, and are incapable of growing during the winter. Seedings made during the winter often germinate during warm periods and are killed by later freezes. Early spring seedings of all except the winter-type grasses are subject to the same hazard. Cool weather usually delays germination and retards seedling development. Seedings made late in the spring or early in the summer are often delayed in emergence by hot drying weather or torrential packing rains. They also suffer more from grasshoppers than do earlier seedings.

Winter-type grasses that are best adapted to the northern part of the region and to elevations approximating to or exceeding 5000 feet may be sown to best advantage in the fall or very early in the spring.

Method of seeding

Drilling usually results in better stands than broadcasting. Clean seed of extremely small-seeded grasses is drilled most satisfactorily with an alfalfa drill or the grass-seeder attachment on an ordinary grain drill. Cotton-planter-type grass drills of the kind developed at the Southern Great Plains Field Station, Woodward, Oklahoma, are recommended to sow light chaffy grasses that cannot be handled with either an alfalfa drill or an ordinary grain drill. These machines, when equipped with double-disk coulter openers and rolling flanges to prevent seeding in excess of 1 inch deep, give excellent results. Nurse crops should not be used as they compete seriously with the seedling grasses.

The seed-bed should be packed with a corrugated surface roller after seeding if the soil is sufficiently protected with a vegetative mulch or by other means to prevent the wind erosion that packing often causes.

Adapted Grasses and Soil Requirements

Many native grasses may be used successfully in revegetation work when their soil and local climatic relationships are considered. Blue grama (*Bouteloua gracilis*) is one of the most valuable native species adapted to a wide variety of soils in the region. Although it shows a preference for the heavier soil types, it occurs on sand and grows well when seeded there.

Buffalo grass (*Buchloë dactyloides*) occurs naturally on heavy and semi-heavy soils, although it has been grown successfully on soils containing some sand. This extremely palatable and highly nutritious grass is more resistant to close grazing and heavy trampling than any other species in the Great Plains. It is equal to blue grama in feeding value and has the added advantage of spreading rapidly by surface runners. Satisfactory methods have been developed in recent years for harvesting the seed which is customarily borne extremely close to the ground. Consequently, the species is being used extensively in reseeding work in the area, although the price is still a limiting factor.

Side-oats grama (*Bouteloua curtipendula*) is a valuable medium-tall native grass and may be used to advantage in mixtures with blue grama and other species on sandy, rocky, pervious soils to which it is best adapted. Other valuable grasses suited for sandy soils include sand lovegrass (*Eragrostis*

trichodes), sand paspalum (*Paspalum stramineum*), and sand bluestem (*Andropogon hallii*). Sand lovegrass and sand paspalum are extremely palatable and highly nutritious bunch grasses for summer grazing. They often spread more rapidly by natural reseeding than any other native species with the exception of the much less desirable sand dropseed (*Sporobolus cryptandrus*). They are more palatable than sand bluestem but the latter is more productive and a better soil binder because it spreads by rootstocks.

Many introduced grasses have been tested in the region but without much success except in the case of a few species. A combination of extremely hot summers and subzero temperatures during the winter has made it extremely difficult to obtain adapted grasses from many other regions of the world. Crested wheatgrass (*Agropyron cristatum*) and smooth bromegrass (*Bromus inermis*) are well adapted to the Northern Great Plains and are considered fairly successful in the foothills and high valleys of Colorado and New Mexico, but are seldom able consistently to withstand intense heat combined with severe drought in the Central and Southern Great Plains.

Italian and perennial ryegrass have proved to be short-lived, relatively unproductive, and poorly adapted to the dry atmosphere of the Plains, although they have given satisfactory results beyond the eastern border of the region where the annual precipitation approaches or exceeds 30 inches. When copiously watered these grasses make suitable winter lawns in dryland areas. Dallis grass (*Paspalum dilatatum*) and Rhodes grass (*Chloris gayana*) have been satisfactory on the coastal area of southern Texas but usually winter-kill farther north.

Turkestan bluestem (*Andropogon ischaemum*) and Caucasian bluestem (*A. intermedius caucasicus*) are the only introduced grasses which have proved to be capable of withstanding hot summers and cold winters throughout the region. These grasses are finer stemmed than the native bluestems, appear to be more palatable, and spread more rapidly by natural reseeding.

Weeping lovegrass (*Eragrostis curvula*), an introduction from South Africa, is one of the most promising grasses of the Southern Great Plains, although it winter-kills sometimes in northern Oklahoma and northern Texas. Its advantages are prompt germination, strong seedling vigor, ease of establishment, rapid vigorous growth on a wide range of soil types, resistance to heat and drought, fair palatability to livestock, and ability to reseed itself.

Lehmann lovegrass (*Eragrostis lehmanniana*), another exotic from South Africa, is considered the most promising grass for reseeding work in southern New Mexico. It is more palatable and more drought resistant than weeping lovegrass but is lower in winter hardiness.

Grass Mixtures

The association of several species common in native stands has been successfully used as a guide in formulating mixtures for reseeding work. A splendid mixture of blue grama and buffalo grass is commonly present on heavy to semi-heavy soils. These species often occur in about equal amounts and together often represent over 90 per cent of the total grass cover on soils of this texture. A much larger number of species usually occur in natural associations on sandy soils or in rocky, "caliche" situations of a pervious

nature. The short-grass association represented by blue grama and buffalo grass is often interspersed with side-oats grama on the caliche spots which characterize many range areas.

The choice of species usable in mixtures is restricted by current limitations in seed supplies of many grasses. A standard mixture commonly used at the present time consists of blue grama as the basic species with side-oats grama for the sandy, caliche spots, and buffalo grass for the heavier soils. A mixture consisting of about 60 per cent blue grama, 30 per cent side-oats grama, and 10 per cent buffalo grass is usually drilled at the rate of about 12 pounds per acre. For sandy soils the proportion of side-oats grama is increased, that of buffalo grass is reduced or eliminated entirely, and generous additions of sand lovegrass, sand paspalum, and sand bluestem are made when seed supplies permit. Limited amounts of weeping lovegrass may be added to the mixture for nearly all soil types in the southern half of the region, although excessive rates of this species should be avoided as it competes seriously with the slower growing natives. Limited quantities of western wheatgrass (*Agropyron smithii*) and Texas bluegrass (*Poa arachnifera*) may be added for heavy and sandy soils, respectively, where it is desired to have a cool-weather species in the mixture. However, since these grasses respond best to fall or early spring seedings, it is considered best to grow them in a separate pasture and rotate grazing between them and the summer species.

Early Management of the Sward

It is commonly recommended that young grass stands should be protected from grazing until the plants are well developed and able to withstand trampling. Preliminary results of limited trials indicate, however, that livestock may be used judiciously to control weeds without unduly harming the young grasses. It is probably safer, however, to exclude livestock during the first and possibly the second growing season depending on the rapidity of establishment.

Young grass stands usually respond to clipping for the control of weeds during the first and often the second growing season. Most native grasses are slow to become established and almost invariably become infested with weeds comparatively soon after seeding, regardless of the method of preparation. Two clippings are usually required to reduce weed competition during the first season. Mowing has the further advantage of leaving a stubble to control wind erosion until thin stands of young grasses become better established.

Successfully established stands of grass have been damaged or destroyed by serious soil blowing from adjacent fields. Young plants are particularly susceptible to this form of injury. The importance of keeping the surrounding areas fully stabilized cannot be too strongly emphasized.

George A. Rogler

UNITED STATES OF AMERICA
Northern Great Plains *

Introduction

The Northern Great Plains in this discussion include an area bounded on the north by the Canadian border, on the east by the eastern boundary of North and South Dakota southward, on the south by the Nebraska-Kansas line westward, and on the west by the Rocky Mountains. It is a region characterized by wide extremes in climate where rainfall is the most essential element limiting crop production. The average annual rainfall varies from approximately 27 inches in the southeastern portion to less than 10 inches in some locations in the northwestern portion (Kincer, 1941). Droughts are irregular but persistent in recurrence. The major portion of the moisture is received during the spring and early summer. This fact has much to do with the type of grassland vegetation that is found. Temperatures are also widely variable from north to south and from year to year in any one locality. The variation between maximum summer and minimum winter temperatures frequently is well over 130° F. Winter temperatures as low as −35° F. and summer temperatures as high as 100° F. are not infrequent in North Dakota and Montana. Temperature, therefore, as well as rainfall helps to determine what species of grass grow throughout the region. Tall grasses are most common in a rather narrow strip along the eastern boundary. These shade into the mid-grasses and short grasses with a predominance of the latter toward the west. The short grass type of vegetation covers the major portion of the region.

During the last 10 years large areas of land which were once cropped and abandoned have been reseeded to grass. In addition, many smaller farm plantings have been made. This has done much not only to reduce erosion but to help in rebuilding hay and pasture reserves as well as in aiding the return of soil to its original productivity and structure.

Plain soils in general have been and still are high in elements essential for plant growth. There has been a growing realization, however, as grass stands have become older and the land cropped longer, of the need for supplemental nitrogen. This has led to the use of legumes alone and in mixtures with grasses. The use of grass-legume mixtures has been limited primarily to a rather narrow belt extending southward along the eastern boundary of the region. Most seedings of grass in the central and west have not included legumes in mixtures. The reason for this has been not only the lack of highly adapted legumes but also the lack of experimentation in which the valuable assets of legumes in mixtures with grasses might be demonstrated. Much is now being done to encourage the use of several grasses in mixtures along with alfalfa or sweet clover. These are the only two legumes which are now known to be well enough adapted for use on the major portion of the Northern Plains.

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* Cooperative investigations between the Divisions of Forage Crops and Diseases, Dry Land Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, and Division of Nurseries, Soil Conservation Service, U.S. Department of Agriculture.

Adaptation

Too much emphasis cannot be placed on the importance of adaptation. Success or failure of grass and legume plantings in the Plains may often be determined by the use of adapted or unadapted species and strains. Two of the most important components of adaptation in this region are drought resistance and winter hardiness.

Northern Plains' grasses can be grouped into two broad classifications based on the period of maximum vegetative growth. These classifications are important in respect to adaptation and time of planting. They are called the cool-season grasses and the warm-season grasses. Cool-season grasses are those which make their maximum vegetative growth during the spring and fall, with a lesser amount of growth during the hot part of the summer. These grasses start growth quickly after the ground thaws out in the spring and if moisture conditions are favorable in the fall they continue growth until late in the season. Warm-season grasses make their maximum growth during the summer. They generally start their spring growth after the last frost in the spring and cease growing by the time or upon the advent of the first hard frost in the fall (Rogler, 1943).

Geographical strains of warm-season grasses react similarly when moved from south to north or vice versa (Rogler, 1941). In general, strains of this group should not be moved either north or south more than 200 miles. Only those of local origin are sufficiently well adapted within a particular locality to be of use under cultivation. Species within this group are all native grasses. Their use under cultivation has been limited to about the last 8 years. Those that are used for reseeding purposes in the Northern Plains are *Andropogon furcatus* Muhl., *Bouteloua curtipendula* (Michx.) Torr., *B. gracilis* (H. B. K.) Lag., *Buchloë dactyloides* (Nutt.) Englem. and *Panicum virgatum* L. Plantings of *A. furcatus* and *P. virgatum* should be limited to the eastern portion of the region, or to locations with favorable moisture conditions in the west, because of their lack of drought resistance. *B. curtipendula* and *B. gracilis* can be used in the western areas with *B. gracilis* being better adapted to extremely dry locations. The lack of seed of *B. dactyloides* has prevented any extensive plantings of this species ; if seed supplies become sufficient, it will be of special value for seeding in the western portion of the region.

Most of the important cultivated grasses belong to the cool-season group. These grasses can, in general, be moved greater distances than the warm-season group without affecting their adaptation. Species in this group that are of importance for cultivation are *Agropyron cristatum* (L.) Gaertn., *A. smithii* Rydb., *A. trachycaulum* (Lk.) Malte, *Bromus inermis* Leyss., *Elymus canadensis* L., *E. junceus* Fisch. and *Stipa viridula* Trin. *A. cristatum* is the outstanding grass for use in the western and drier locations in the region. *B. inermis* is of equal importance for seeding in the eastern and more favorable locations. Their areas of adaptation overlap ; therefore, the two species can be used successfully in many of the same localities, particularly in the central region.

In the case of bromegrass, work done by Newell and Keim (1943) indicates the importance of using strains only of southern origin in Nebraska. " The

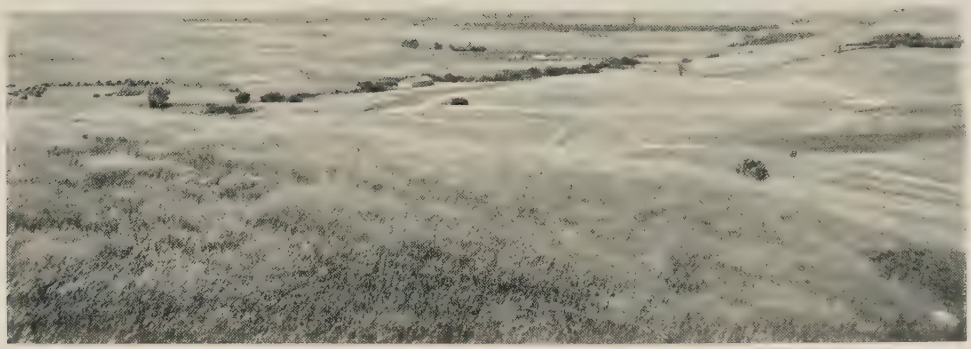

Fig. 64.—A typical view of the vegetation and rolling topography of the Northern Great Plains. The more level areas are cultivated, while the remainder of the land has been left in native grass.

Fig. 65.—Cultivated area in the Northern Great Plains typical of that on which cultivated grasses are established.

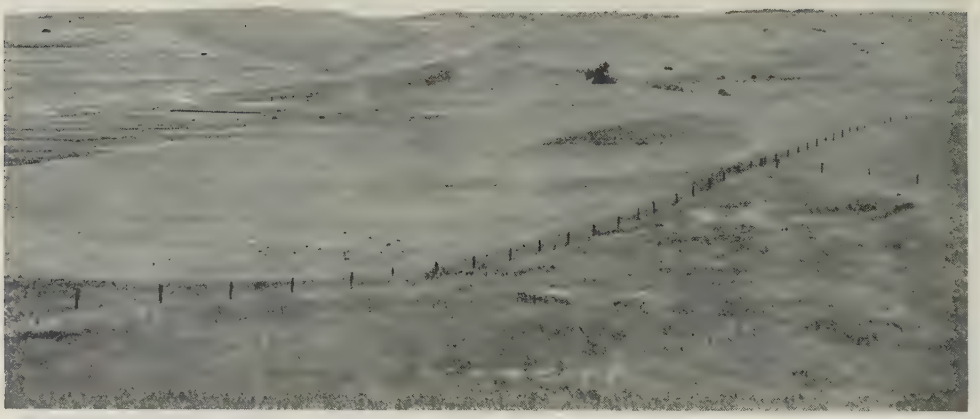

Fig. 66.—General view of rolling topography of the Northern Great Plains. A farm shelterbelt can be seen in the right background. Crested wheatgrass has been established in the centre foreground.

Fig. 67.—Northern Great Plains Field Station, Mandan, North Dakota, situated in an area typical of the Northern Great Plains.

strains of the southern type produced more vigorous seedlings under short days of fall and early spring, were more tolerant of drought and heat, possessed more vegetative vigor, and were more productive under the conditions of the test than the strains of the northern type." Unpublished data from the Northern Great Plains Field Station, Mandan, North Dakota, show that differences between northern and southern types are not so pronounced at that location and that southern types are winter hardy and can be used successfully in the north.

The other grasses listed in the cool-season group may be used in combination with either *A. cristatum*, *B. inermis*, or with both. *A. smithii* and *A. trachycaulum* are best adapted for central and western seedings. *E. canadensis* can be used in the eastern and central portions successfully. The range of adaptation for *E. junceus* and *S. viridula* has not been accurately determined, but both are of enough promise to warrant their trial in mixtures in any portion of the region.

Alfalfa and sweet clover are the only known legumes that are well enough adapted to be grown to any extent in the Northern Great Plains. In the central and western part of the region, alfalfa is sometimes killed by severe drought and subsequent winter injury, even after it is well established, but because of its high value, particularly for hay, reseedings have generally been made. In the drier sections plantings should be made on locations with a more favorable moisture supply. Hardy varieties such as Grimm, Ladak, Cossack and Ranger are the only ones that can be grown successfully. Varieties of southern origin are likely to winter-kill. Ladak is especially valuable for use in the centre and west because it gives a higher percentage of its seasonal yield in the first cutting than other varieties. One cutting is all that is generally obtained from any variety in the drier areas.

In most years soil moisture is reduced by the time the first cutting is made to a point where recovery is slow. Occasionally, however, two cuttings can be made. Toward the eastern portion three cuttings may be obtained from varieties such as Grimm. Ladak has been reported to do especially well in mixtures with grasses when used for pasture. Grimm is used quite extensively. It is susceptible to bacterial wilt and should not be used in locations where the disease is a problem. Ranger is a new variety resistant to wilt. Seed has not been available long enough or in large enough quantities to plant a very large acreage.

Sweet clover is adapted to the entire region and is grown extensively for pasture and to a lesser extent for hay. It is highly drought resistant; but, because of its biennial nature, must be managed carefully to allow enough seed production to maintain stands over a period of years. The varieties of sweet clover now grown most commonly are Common Yellow, Common White, and Grundy County. Common Yellow has come to predominate in much of the region as stands seem to be maintained with greater certainty. This variety ripens early, and seed production in drought years has been more abundant than on other varieties. A large proportion of commercial seed stocks are mixed white and yellow with an increasing proportion of Common Yellow in the mixture.

New varieties that have outyielded Common Yellow and Common White both for pasture and hay during the last few years at the Nebraska Agricultural

Experiment Station, Lincoln, Nebraska, are Evergreen, Spanish and Madrid (Garver, Slatensek and Kiesselbach, 1943). They range from exceptionally late to medium early, maturing in the order listed. The first two are white-flowered varieties. Madrid is yellow-flowered. The varieties all have vigorous seedlings and are superior in competing with weeds the first year. Unpublished data at Mandan, North Dakota, indicate high superiority for Madrid both as hay and pasture.

Mixtures

The success of mixtures of grasses and legumes depends on the compatibility of associated plants, not only with respect to habits of top growth, but also with respect to root interrelationships (Ahlgren and Aamodt, 1939). Symbiotic interrelationships between grasses and legumes may be due to differences in nutritive requirements or habits of root growth of the associated plants which permit more efficient use of the soil and to the production of nitrogen by the legume (Roberts and Olson, 1942). Other advantages of growing mixtures are that the hazards of seeding two or more species may not affect them equally, so that a mixed seeding is more certain to give a stand than a pure seeding. Diseases and insect pests may not attack all species within a mixture to the same extent (Franzke and Hume, 1942). Fields that are seeded may vary in topography, with certain areas particularly suited for different species. The soil may also vary in structure, texture and fertility. A mixture of plants can, of course, meet these variations much better than a single species (Whitman, Stoa and Hanson, 1939). The addition of a legume to a mixture will generally increase the total production and the nutritive value of the pasture. Because of differences in time and type of growth, grazing may be extended and the yield increased.

In spite of the recognized advantages of mixtures, few experimental data are available. The actual interrelationships of associated plants and their effect on yield and gains need further investigation. Most mixtures must yet be considered as compounded more or less empirically.

Many different mixtures have been suggested for various areas in the Northern Great Plains region. For the purpose of this discussion, however, it seems necessary to give only the basic components of all mixtures in the different geographical areas. *Bromus inermis* should be the basis of mixtures in the eastern portion and *Agropyron cristatum* in the western portion. Approximately 50 per cent of the seed mixture by weight should consist of one or the other of these species in their respective areas. Both species can be used together in most of the region, except in eastern Nebraska where *A. cristatum* is not well adapted. Lesser quantities of seed should be used of either species in the mixtures where one or the other is not so well adapted. Other grasses discussed under adaptation should be used in mixtures depending on the area in which they are adapted. Warm-season grasses can be used to advantage in mixtures with cool-season grasses. The use of these two types of grass together helps to extend the grazing season. Better weed control may be obtained also by using a mixture of the two types. Stands of cool-season grasses often become weedy during their summer dormant period, when seeded alone. Warm-season grasses will do much toward eliminating the weeds.

It is profitable to use either alfalfa or sweet clover in all mixtures. The legume may make up as much as 20 per cent of the seed in mixture in the eastern area, but not over 10 per cent in the central and western areas where moisture is a more limiting factor. The rapid growth of the legume may result in too much competition to the grass in the early stages of establishment. Alfalfa can be used successfully in mixtures with grass in the eastern area, but should be replaced or included with sweet clover farther west. Both legumes may be used in the central area.

Unpublished data from the North Dakota Agricultural Experiment Station, Fargo, indicate some of the advantages of grass-alfalfa mixtures when harvested for hay. Stands were established in 1931 and yields taken for a 10-year period from 1932 to 1942. The average yields over this period were: *B. inermis* alone 4065 pounds, alfalfa alone 3978 pounds, and the mixture 4807 pounds. The grass-alfalfa mixture yielded better than grass alone in 7 of the 10 years. After 10 years the grass-alfalfa plot had a more healthy color and appeared somewhat less " sod-bound " than the plot where the grass was seeded alone.

It is difficult to maintain stands of alfalfa or sweet clover in mixtures with grasses in the central and western portion of the region except in local situations where moisture conditions are favorable. Attempts in Montana to establish permanent grass/sweet clover mixtures by reseeding sweet clover on 2- and 3-year-old grass stands in the early spring failed in the 2 years tried (Reitz, Bell and Tower, 1936). Enough advantage is gained, however, by using sweet clover in mixture to warrant its use even though stands of this legume are maintained for only 2 years. Good grass-alfalfa mixtures can sometimes be obtained by seeding grass in badly depleted dry-land alfalfa fields where alfalfa cannot be successfully re-established. Grass will bring these fields back into production and help to control weeds.

Establishment

Time of seeding

There are four different periods for seeding grasses and legumes which may be considered. These are late summer or early fall, late fall, early spring and mid-spring. Late summer seedings are those from about August 15 to September 15, in which the seed has time to germinate and seedlings become well-established before winter. Plantings made at this time are, in general, the most successful, providing sufficient moisture is available for germination and growth and grasshoppers are not present in sufficient numbers to cause damage. Alfalfa and sweet clover can generally be successfully seeded during this period from the North and South Dakota line southward without danger of severe winter killing, except in those cases when the seedlings do not become well-established before freeze-up. From there northward the hazards of winter-killing are too great for seeding legumes at this time. In occasional years, however, successful plantings can be made of alfalfa and sweet clover even in the north in the late summer. Warm-season grasses cannot be seeded successfully at any place in the region during this period because of their unfavorable response to cool fall weather and subsequent winter killing (Rogler, 1943). The chief advantages of late summer seedings are that there is less competition

from weeds and better establishment of plants by the time that heat and drought become serious during the following summer.

Late fall seedings are those made so late in the fall that germination will not occur until the following spring. This period of planting has been very successful in all portions of the region except from approximately the northern boundary of Nebraska southward. Its greatest use has been in seeding abandoned areas without soil preparation and in stubble-land. Germination occurs very early in the spring. Alfalfa and sweet clover can be successfully established by planting during this period, but it is desirable to use seed that has not been scarified or, in the case of sweet clover, unhulled seed. The advantages of late fall seedings are that they are not dependent upon favorable moisture conditions at the time of seeding. They are also less subject to grasshopper damage than those in early fall or mid-spring. Seedings at this time may be extended over a longer period and are better adapted for planting large acreages. This is also the best period to seed land that has been damaged by blowing and which has a weedy cover (Westover and Rogler, 1941). Seedlings will start growth before it is possible to get in the field in the spring.

Early spring plantings are used extensively with successful results throughout the entire region. This is one of the best times to plant mixtures containing alfalfa or sweet clover. There is some danger of frost injury to the legume seedlings, but it is better to plant early and risk this hazard than to delay planting and increase the possibility of losing the stands later as a result of hot, dry weather (Frolik and Frolik, 1941).

Mid-spring plantings are those made after the soil has become warm in the spring and after the first crop of weeds has germinated. This crop of weeds may be destroyed by cultivation before seeding. Best results have been obtained with warm-season grasses when seeded during this period because they germinate and grow rapidly at warm temperatures. There is also less competition from weeds because of previous cultivation (Newell, Conard, Klingman and Keim, 1943).

Rate of seeding

Many factors influence the rate of seeding. The most important of these are the quality of seed, seed size, moisture supply and type of planting such as for seed production, hay or pasture. The use of clean, heavy seed of high germination cannot be too strongly emphasized. Seed quality has greatly improved during the last few years with the advent of better harvesting and processing methods, but many plantings are still being made with light, trashy seed (Weber, 1941). Nothing except lack of adaptation or deficient moisture supply can be so important in the establishment of stands as high quality seed. The sowing rates that are suggested in this discussion are based only on seed of high purity, germination and seeding quality.

In the eastern portion of the region a seeding rate of from 12 to 17 pounds per acre should be used in the establishment of hay and pasture plantings. The rate for grass-legume mixtures may be slightly heavier than that for seeding grass alone. As moisture conditions become less favorable toward the central and west, the rate of seeding should be reduced, as too heavy a stand will decrease yields. The rate may vary in drier regions from 7 to 12 pounds,

and even from 4 to 6 pounds in the extremely dry localities. Many successful stands have been established at these low rates Plantings for pasture may be made at a higher rate than those for hay, to give a fine, denser turf. Row seedings are seldom made except for seed production ; but when this type of planting is made the seeding rate may be reduced to approximately half that used for solid seedings.

Depth of seeding

Many experimental data are available on the proper depths to seed grasses and legumes. These data emphasize the necessity of shallow seedings. The proper depth of seeding is influenced by the species, size of seed, soil type and moisture conditions. Ordinarily, planting depths should be no greater than 0·75 inch. In light, sandy soil most species can be successfully seeded up to 1 and 0·5 inch in depth. *Agropyron smithii, Bromus inermis, Elymus canadensis* and *Stipa viridula* have greater ability to emerge from deep plantings than most other species. The warm-season grasses should never be seeded deeper than 0·5 inch and less than this if possible.

Seed-bed preparation

Loose, poorly prepared seed-beds are often the cause of failure to establish stands. The soil must be firm in order to make shallow seedings and to enable the seed to be placed in close contact with the soil. The surface will retain moisture longer if well packed and germination will be more rapid. Seed-bed preparation is similar for the central and western portions of the region but along the eastern boundary it is somewhat different. In this latter area land that was in corn or some other cultivated crop or in summer fallow offers a desirable seed-bed for late summer plantings provided weeds have been kept well in check and there is no danger from blowing. A light surface tillage is generally necessary directly before seeding. In the southeastern portion it is generally advisable to plow the land well in advance of seeding. Additional precautions must be taken on plowed land to assure a firm seed-bed. It may be necessary to use a corrugated roller or a disk set straight to achieve this result. In the case of spring plantings fall-plowed land is most desirable. Tillage operations that leave the soil too fine or the surface too smooth should be avoided.

The use of the above types of well-prepared seed-beds in the central and western areas cannot be safely recommended except in situations that are similar to those in the area just described or for special seedings on small acreages. A well-prepared seed-bed in the central and western areas generally means one on which the surface has been undisturbed by tillage. In this portion of the region where rainfall is often inadequate, the primary considerations are not so much those of tillage as in providing protection for young seedlings, preventing soil erosion, and at the same time conserving the largest possible amount of soil moisture. Clean grain stubble furnishes one of the best preparations for late summer seeding. Drilling the seed under such conditions permits the seedlings to make considerable growth before winter, and the stubble protects them from danger of soil blowing. Snow that is caught will form a cover which will greatly lessen the danger of winter-killing

and will provide moisture for early and rapid spring growth. In the northern areas where alfalfa and sweet clover cannot be safely seeded in the late summer, it will be necessary to plant the legume seed the following spring in the grass stand. This can best be done by planting the grass in 12- or 24-inch rows and then drilling the legume in alternate rows the following spring so that the grass seedlings will not be damaged by the drill.

Grain stubble also furnishes a desirable seed-bed for late fall seedings. On abandoned fields seedings can be made during late fall directly in the weed cover with good assurance of success. If the land is hard and baked or badly cracked, a light disking will improve it for seeding. If the field has been abandoned for such a long period that a heavy growth of perennial weeds is present, it may be desirable to plow or one-way disk early in the spring and seed to a cereal crop. Plantings of grasses and legumes can then be made in the stubble during the late fall.

Early spring plantings may be made in stubble or on protected corn land. Spring plantings made on fallow land generally become very weedy in the first season. Experiments at the Northern Great Plains Field Station, Mandan, North Dakota, have shown that, in plowed fallow, cultivation tends to keep the surface soil dry, so that weed seeds will not germinate during the fallow season. Consequently, if present, they germinate the following spring with the grass seed (Sarvis and Thysell, 1936).

Mid-spring plantings may be made on corn ground and on spring- or fall-plowed stubble. In all cases it will be necessary to prepare a firm seed-bed, especially if the soil has been worked to kill a crop of weeds just before seeding. A good rain will often consolidate the soil enough for a suitable seed-bed. If a rain does not come at the right time it may be advisable to pack the soil before planting.

Method of seeding

In general, seed should always be planted with a drill as it distributes the seed uniformly and more nearly places it at the proper depth for good germination and establishment. The double disk, single disk, or deep furrow disk type drills may be used. On well-prepared soil either the double disk or single disk drills are satisfactory. The single disk drill is better adapted for use where the soil surface is hard or where it is desirable to leave the soil surface rough. Deep furrow disk drills have been used extensively and successfully for planting abandoned land where the seed-bed is firm and where it is necessary to cut through weedy growth and trash.

Broadcasting can be used more satisfactorily in the more moist portion of the region than under dryland conditions, but even in these areas drill seedings are superior. In local conditions where the land is too rough for machinery, broadcasting is sometimes successful. Where broadcasting is necessary, some type of implement such as a disk or harrow should be used to aid in covering the seed.

On limited acreages and on unstable soils, hay that contains mature seed may be spread over the surface and then disked or pressed into the soil to afford some covering. Good emergence is generally obtained by this method as the hay helps to retain moisture and affords considerable protection to the seedlings.

When grasses and legumes are seeded at the same time they may be mixed in proper proportions. The seed should be mixed rather frequently during seeding as the legume seed will tend to work down through the grass seed. If a grass-clover seeding attachment is available on the drill, the grass and legume may be seeded separately either in the same row or alternate rows. Grass seed that has been properly cleaned and processed can be sown satisfactorily through a drill, but grass seed agitators installed in the drill will aid in getting the seed to feed uniformly through the drill cups.

The drill spacings may be wider in the drier parts of the region than in the more moist areas. A 12-inch drill spacing in the dry areas will allow the planting to be made at a uniformly low rate and at the same time produce a stand sufficiently thick for the amount of soil moisture available (Clarke and Heinrichs, 1941). In spacing over 1 foot apart the grass may not control weed growth unless cultivation is practiced. A 6-inch spacing may be more desirable for pasture purposes. Cultivated row plantings generally give greater average yields of hay than those close-drilled. The expense of cultivation and the lowered quality of hay due to a coarse growth make the use of row plantings inadvisable for this purpose, however. There is also greater danger from erosion in row plantings and soil often accumulates in the rows from blowing, causing the hay to be dirty when harvested.

Companion or nurse crops should not be used with grasses or legumes where there is a scarcity of rain in mid-summer. Under these conditions competition for moisture may be too great for the survival of small grass or legume seedlings. In North Dakota flax is the least undesirable of the crops used. This should be seeded with grass only when it is necessary to have some return from the land in the first year of seeding. When flax is used as a nurse crop, light seedings of it should be made. In the extreme eastern part of the region spring grains are sometimes used with grasses and legumes the first year. The nurse crop should be planted at a much reduced rate and should be removed before maturity.

Management

The maintenance of stands of grasses and legumes depends greatly upon proper management methods. Climatic conditions in different parts of the region and from year to year influence these methods. General suggestions may be made, however, which will be appropriate for certain areas in most years.

Grass-legume mixtures ordinarily should not be grazed or cut for hay the first year. Occasionally when seed is planted in the late summer on fertile soil which has a favorable moisture content, enough growth will be made the first year so that a light crop of hay may be harvested or a small amount of forage available for grazing in the fall. Weed growth is generally rather heavy the first year, especially where late fall or spring plantings have been made. Clipping of the weeds should be resorted to only when they are so tall and vigorous that the grass or legume seedlings are seriously hampered in their growth. Clippings should be made if possible before the arrival of hot, dry weather and on a cool day. The weeds should be cut high in order to

leave considerable stubble and in order not to cut off the grass or legume seedlings. High stubbles will give some protection to the seedlings from the heat and drying effects of the sun and wind. Stubble will also catch snow for winter protection and subsequent early spring moisture. In the central and western parts of the region no special care is ordinarily needed in the first year of seeding. Weeds which grow during the summer may be left on the field for protection to the seedlings during the winter. Weeds also often help to give some protection from grasshoppers. During years of heavy grasshopper infestations, poisoned bait should be spread over fields seeded to grass. Seedlings are readily killed by grasshoppers if eaten off before they become well established. As the plants become larger, little injury will result to grass, even though the leaves may be stripped off to the stem.

Early in the spring following the accumulation of a heavy growth of weeds, all weeds and vegetative growth should be mowed and removed. It is never advisable to burn the old growth because of the serious damage it may do to the grass or legumes. Stands are usually well enough established by the second year, so that weeds are not a serious problem after this time. It may take from 3 to 4 years, however, for stands to become well enough established to control weeds in abandoned land seedings.

After stands are established, proper management must be practiced to maintain them. *Bromus inermis* and *Agropyron cristatum* may be grazed in the spring after they have had time to make approximately 5 inches of growth. *A. cristatum* in particular should be grazed heavily enough to keep down the production of seed stalks, as this species becomes coarse and unpalatable as it reaches maturity. *B. inermis* retains its palatability somewhat longer. Most cool-season grasses become more or less dormant after maturity or during the summer months. Their greatest usefulness is as a supplement to native range. They can be grazed from 2 to 3 weeks in the spring before native range is ready and at a much higher rate. When native range is in the best condition for grazing, livestock can be taken off the cultivated grasses and any growth remaining may be cut for hay. Mixtures of grass and legumes may extend the grazing period on cultivated pastures considerably as the legume will furnish an abundance of feed later in the season. If sweet clover is grazed too closely the second season sufficient seed will not be produced to maintain stands of the legume. Even if seed is produced moisture conditions must be very favorable the following season for seedlings to become established among the older plants of grass. With favorable moisture conditions in the fall, cool-season grasses will make sufficient growth for grazing. Close fall grazing of alfalfa in grass-alfalfa mixtures will tend to eliminate the alfalfa. Every effort should be made to keep the legumes maintained in the mixture because such mixtures are highly palatable and nutritious and make splendid feed for all classes of livestock.

When grass-legume mixtures are cut for hay, it is important to harvest them at the proper growth stage in order to obtain the highest quality feed. In the case of mixtures they should be cut at a time to suit the crop that constitutes the greater portion of the yield (Clarke and Heinrichs, 1941). Fortunately, both *A. cristatum* and *B. inermis* can best be cut for hay at about the same time that alfalfa or sweet clover should be cut. *A. cristatum*

should be harvested when the grass is fully headed. Cutting of bromegrass can be delayed until bloom stage. Alfalfa should be harvested soon after the first flowers appear and before one-half of the flowers are open. Sweet clover should be harvested near the beginning of the flowering period.

Grass and legume mixtures when used in rotation with other crops should be left down long enough to reduce weeds and crop disease organisms as well as to improve the soil. Experience with bromegrass at the Northern Great Plains Field Station, Mandan, North Dakota, proved that 3 years was not long enough to establish a good sod, nor was it long enough to reduce weeds (Thysell, 1941). It is suggested that grass be left down at least 6 years. Investigations are now under way to determine the optimum period to leave grass in crop rotations. Flax is the best crop to follow newly plowed grass in North Dakota.

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The Intermountain and South Pacific Coast area includes Nevada and Utah, southern Idaho, Missouri River drainage of southwestern Montana, those parts of Wyoming, Colorado, and New Mexico not in the Great Plains, and all of Arizona and California. Pasturage information is classified both on a geographic and an agricultural basis.

Geographically, the problem of mixed seedings falls into two divisions: (1) the mountain and plateau country with cold, snow-covered winters and cool summers, except from mid-June to the end of August when maximum temperatures usually reach 90° to 100° F.; (2) the low, hot country of New Mexico, Arizona and California where winters are mild, often without snow, and the summers are hot (100° to 115° F.) from May to September.

Agriculturally, the problem has four aspects: (1) irrigated pastures, (2) dry-farm pastures, (3) reseeded range lands, and (4) hay mixtures. The four agricultural aspects occur widely scattered throughout the entire area in both geographical divisions.

Irrigated Pastures

Species mixtures. Mixed species of grasses and legumes are generally accepted as being superior to single species for irrigated pastures, whereas single species are used in general practice for the growing of hay. The superiority of mixed species over single species for pasture lies in the greater yield, the shorter time required to get pasturage ready for grazing, the more continuous supply of green pasturage throughout the season, and a more varied diet for the animals. In Colorado (Robertson, Weihing and Stewart, 1942), for example, mixed grasses and red clover gave 1·87 tons of pasturage, mixed grasses and sweet clover 1·17 tons, and mixed grasses without legumes 0·76 ton. In Utah (Keller, 1943) yields of alfalfa mixed with grass gave significantly higher yields than clovers with grass or merely grass mixtures, and all of these higher yields than one or two grasses alone. Species that start rapidly such as domestic and perennial ryegrasses, and clovers, especially Ladino where it is adapted, shorten the time (Jones and Brown, 1942) required to prepare new seedings for the first grazing.

When well-chosen, one component of the mixture provides green feed early in the spring (orchard grass), another soon after (smooth brome), and others in midsummer (alfalfa, or Dallis grass where favored). The longer period of green feed rich in protein, minerals and vitamins (Orr, 1929) and the feed variety also favor the mixed pasture for livestock, especially when legumes are included. Deep-rooted alfalfa during drought periods draws water from greater depths (Weaver, 1926) than more shallow-rooted grasses. Bromegrass and red clover are deeper rooted than Kentucky bluegrass and white clover. These differences in rooting habits are, however, probably more important theoretically than practically, except in the case of alfalfa.

No record exists of the seed mixtures that are actually being sown. It is thought, however, that pastures are sown to mixtures that are in close accordance with those recommended by various technical agencies. State

Fig. 68.—High-producing irrigated pasture at Dairy Experimental Farm (cooperating Utah Agricultural Experiment Station and U.S. Department of Agriculture), near Logan, Utah. View of a diversified farming area. This pasture is seeded to Mixture I in Table 2. (Courtesy Professor George Q. Bateman, Utah State Agricultural College.)

Fig. 69.—Dairy cattle grazing on irrigated tame-grass pasture, Huntley, Montana. One acre of pasture from Mixture I, Table 4, carried 2.15 cows for a period of 140 days. (Courtesy Dan Hansen, Agricultural Superintendent, Huntley Project.)

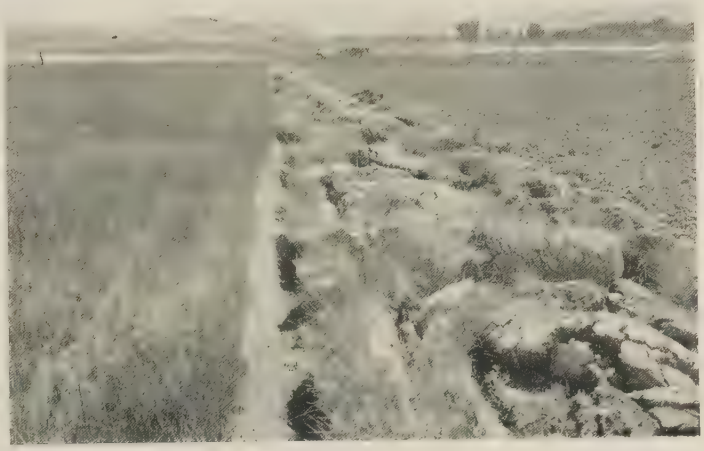

Fig. 70.—Preparing seed-bed for seeding mixture pasture. Left: fresh plowing; right: seed-bed ready for seeding grass and legume seeds. (Photo by U.S. Soil Conservation Service.)

Fig. 71.—Pasture seeded and corrugated ready for irrigation, Pima, Arizona. Water is applied in furrows until stand is established, after which water is flooded between large border dikes. (Photo by U.S. Soil Conservation Service.)

Fig. 72. -Dry-farm pasture of crested wheatgrass near Almo, Idaho. This is a highly successful stand and will produce a high yield. (Photo by U.S. Forest Service.)

Fig. 73. Sagebrush range with all native grasses and herbs practically eliminated as a result of overgrazing. Benmore, Tooele County, Utah. Grazing capacity one A.U.M. on 10 to 12 acres. (Photo by U.S. Forest Service.)

Fig. 74.—"Breaking" sagebrush cover with a "wheatland plow," preparatory to being drilled on mountainous foothill range land, Utah. Such land after plowing is allowed to settle a few weeks before being seeded with a disk drill. (Photo by U.S. Forest Service.)

Fig. 75.—Cattle on pasture largely crested wheatgrass, seeded to Mixture II, Table 8, but without alfalfa. Grazing capacity one A.U.M. per acre 4 years after seeding. Figs. 76 and 77 constitute an adjacent comparison before and after seeding. (Photo by U.S. Forest Service.)

Fig. 76.—Deteriorated range land near Mexican Springs, New Mexico, eroding as a result of destruction of plant cover. (Photo by U.S. Soil Conservation Service.)

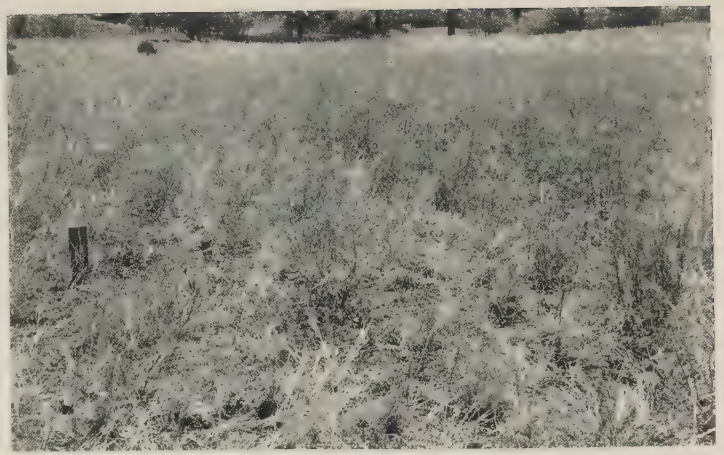

Fig. 77.—Same area shown in Fig. 76 three years after being reseeded to crested wheatgrass, western wheatgrass and sweet clover. (Photo by U.S. Soil Conservation Service.)

Fig. 78—Lehmann lovegrass in October 1940 after being seeded in June 1940 into ripper-cut contour furrows on flat adjacent to Arivaipa Creek, Graham County, Arizona. (Photo by U.S. Soil Conservation Service.)

Fig. 79.—Abandoned cultivated land on Cherry Creek drainage near Denver, Colorado. The land was contour furrowed and reseeded to smooth bromegrass for pasture and for control of flood run-off. (Photo by U.S. Forest Service.)

Fig. 80.—Open aspen stand in Central Utah injured by overgrazing with range livestock. (Photo by U.S. Forest Service.)

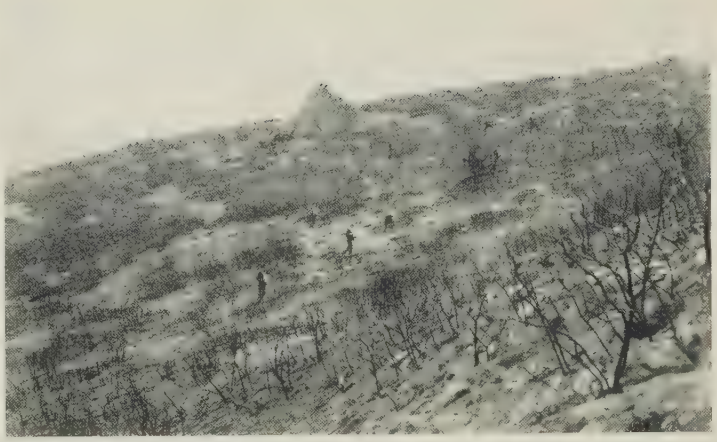

Fig. 81. Hand reseeding on a burned-over watershed from which Salt Lake City draws its culinary water supply, Parley's Canyon, Utah. Heavy ashes immediately after the fire helped to cover the seed. This area was seeded to Mixture III, Table 9, and succeeded remarkably well. (Photo U.S. Forest Service.)

Fig. 82.—Open aspen stand two years later than shown in Fig. 80. Seeded to various grasses named in Mixture VI, Table 9. In open aspen seed need not be covered with soil if seeded during leaf fall. (Photo by U.S. Forest Service.)

Fig. 83.—Tall oatgrass in cut-over and burned-over timberland on Bitterroot National Forest, Western Montana. The seed in this case was broadcast. Elevation about 5000 feet. (Photo by U.S. Forest Service.)

experiment stations, extension services and other agencies, after more than a generation of experience in some States and somewhat less in other States, recommend the mixtures shown in Tables 1 to 7.

These mixtures represent the crystallized thinking of the various State and Federal agencies conducting research, providing extension service or directing "action" programs. The mountain and plateau division is characterized by orchard grass, meadow fescue, smooth brome, perennial ryegrass, white and alsike clovers, and alfalfa, with redtop, reed canary grass,

TABLE 1

Recommended Seed Mixtures for Irrigated Pastures—Nevada
(Fleming and Brennen, 1940)

Species	Seeds—pounds per acre—1940							
	I	II	III	IV	V	VI	VII	VIII
Meadow fescue	5	6	5			5		
Orchard grass	3	5	4			3		
Timothy	3	4	3	6		3	5	
Redtop			4	6			5	
Kentucky bluegrass	5							
Smooth brome					4			5
Crested wheatgrass					4			5
Slender wheatgrass					4			
Reed canary grass							3	
White Dutch clover	4		2					
Alsike clover		2	2	4			4	
Alfalfa		3				7		
Sweet clover								5
Total	20	20	20	16	12	18	17	15

I and II, Medium to good soil, good drainage.
III, Medium to good soil, wet with fair drainage.
IV, Poor to medium soil, wet with poor drainage.
V, Dry benchland, with partial irrigation or with favorable precipitation.
VI, VII, and VIII, For hay with second growth for pasture, for conditions paralleling II, IV, and V.

sweet and strawberry clovers for wet or alkali lands. In the low, hot country the species are domestic ryegrass, orchard grass, Dallis grass, Harding grass, Ladino clover, bur clover, and alfalfa, with Rhodes grass, sweet and strawberry clovers for wet and alkali lands.

It should be noted that subterranean clover, so popular in Australia and previously favored here, is not listed, and Ladino clover is listed only for localities where winters are mild. Ladino is being widely grown in experimental trials in the mountain and plateau division and may be later added to the mixtures, depending on the result of trials (Utah Station, 1943). In spite of its almost universal occurrence in the irrigated pastures of the mountain division, Kentucky bluegrass receives little mention, partly because it comes in naturally on wet land and partly because it produces little pasturage in July and August

when the weather is hot (Bracken and Evans, 1943; Fenske, 1942; and Piper, 1924). It was formerly very popular but has been largely replaced in seeding mixtures by meadow fescue and smooth brome, which with irrigation keep green for a much longer period during hot weather and produce more forage. Meadow foxtail, favorite for wet land in many areas, is barely mentioned. The ryegrass and clovers develop rapidly and yield much more pasturage in the first and second years after seeding than the long-lived perennial grasses.

TABLE 2

Recommended Seed Mixtures for Irrigated Pastures—Utah
(Bracken and Evans, 1943, and Utah A.E.S., n.d.)

Species	Seeds—pounds per acre—1942						
	I	II	III	IV	V	VI	VII
Smooth brome	4		3	3	4		
Meadow fescue	4	4	4	3			
Kentucky bluegrass	4	3			5	14	
Perennial ryegrass	3	4	3	3			
Orchard grass	3		4		3		
Redtop		3					
Reed canary grass				3			
White Dutch clover	3	2	2		2	10	
Alsike clover	2	4			2		
Red clover			3				
White sweet clover				3			8-10 [1]
Yellow sweet clover			3		2		8-10 [2]
Strawberry clover				2			
Alfalfa					2		8-10 [3]
Total	23	20	22	17	20	24	24-30

[1] Soil damp, light alkali.
[2] Soil very damp to partly waterlogged, appreciable alkali.
[3] Soil well-drained, usually gravelly, alkali none to moderate.

I, Good soil, well-drained.
II, Good soil—naturally damp, no alkali.
III, Soil, naturally damp, light alkali.
IV, Soil partly waterlogged, appreciable alkali.
V, Benchland soil, usually underlain with gravel.
VI, A mixture used many years ago.
VII, One species alone, depending on conditions.

A marked speculative interest now exists among workers (Utah Station, 1943) of several research agencies for less complicated mixtures. The new idea is a mixture of one or two grasses and one or two legumes particularly adapted to given conditions. If the idea is supported by trials it will be a new step, although protracted tests may prove that the whole environment, including soil heterogeneity, is too complicated for simple mixtures. It will require some years to establish any marked dependable change in species.

Soil and fertilizer. Because many grades of land are used for pasture,

forage returns and fertilizer needs vary widely. Generally, irrigated pastures of ordinary quality carry from one to two animal units per acre for 4 to 6 months. Good pastures provide as much as two and a half to three animal units of forage to the acre for the grazing season of 3 to 6 months. The capacities therefore range from 4 to 18 animal months of feed (Fenske, 1942, and Utah Station, 1943) with 9 to 12 most common. Hundreds of pastures are less productive but capacities within the range given for good soil afford much opportunity for improvement. Under extensive livestock production

TABLE 3

Recommended Seed Mixtures for Irrigated Pastures—Southern Idaho (Welch, 1917; Fourt, Loughray and Rogers, 1940; and Fenske, 1942)

Species	Pounds per acre—1917				Pounds per acre—1940		
	I	II	III	IV	V	VI	VII
Smooth brome	5	8		12	4	4	5
Orchard grass	5	8		8	6	6	4
Meadow fescue	4		4		8	8	4
Kentucky bluegrass	4						
Timothy	4	4	6				
Crested wheatgrass							5
Redtop			8				
Alsike clover	2	2	2		(2) [1]	2	2
White clover						(2)	
Ladino clover					2		
Total	24	22	20	20	20	20	20

[1] Named as desirable additional or alternate species.

Southern Idaho, 1917:
I and II, Good irrigated land.
III, Low, poorly drained lands.
IV, High lands likely to be dry.

Southern Idaho, 1940:
V, Lower Snake River Valley, abundant irrigation.
VI, Upper Snake River Valley, abundant irrigation.
VII, Limited supply of irrigation water.

lands handicapped with stumps, rocks, uneven topography, alkali, or swamps are used for pasture. Under intensive dairy production the most accessible and the highest producing lands are laid down to pasture. Each grade of land indicated, and a whole series of grades between, are properly devoted to pasture under some existing condition.

All pasture plants recommended, save only alfalfa, do well with about a foot of well-drained soil. Those adapted to wet land thrive with only 4 to 6 inches of soil above a water-table, though yields are less than on deeper soil. Deep, well-drained soils also maintain green feed for longer and more continuous periods than do shallow or waterlogged soils.

Proper fertilization (Bateman, 1943*a*; Peterson, 1943; and Pittman and

Thorne, 1941) also increases yield and prolongs the period during which the pasturage will keep green and therefore more nutritious. In all parts of the region an application of 6 to 10 tons of farm manure to the seed-bed will greatly improve the rapidity and vigor of seedling growth, partly by supplying nitrogen and partly by improving moisture conditions and tilth of the seed-bed. The vegetation, especially the legumes, on soils naturally low in phosphorus responds at once to phosphatic fertilizers. Individual soil types are far too numerous to catalog even where deficiencies are at present known, which in many cases

TABLE 4

Recommended Seed Mixtures for Irrigated Pastures—Montana (*Hansen*, 1924; *Reitz, Bell and Tower*, 1936; *Post and Tretsven*, 1939; *and Williams and Post*, 1941)

Species	Pounds per acre—1939					Pounds per acre—Huntley—1924			
	I	II	III	IV	V	VI	VII	VIII	IX
Smooth brome	3-4				4-6	2	2		8-11
Kentucky bluegrass	4-6					4	4	4	
Orchard grass	4-6				3-4	5	5	5	
Meadow fescue	3-4					3	3	3	
Timothy		5-8							
Reed canary grass		4-5							
Redtop		5-6							
Western wheatgrass			10-14	10					
Crested wheatgrass					4-6				8-11
Tall oat grass					3-4				
Perennial ryegrass						3	3		
White Dutch clover	1-2					2		2	
Alsike clover	1-2	2-3				2		2	
Strawberry clover			5-6						
Astragalus rubyi				6-10					
Yellow sweet clover					2-4				
Total	16-24	16-22	15-20	16-20	16-24	21	17	16	16-22

I, Good land, well-drained, ample irrigation water.
II, Wet or poorly drained soils.
III and IV, Alkali land, poorly drained or seeped.
V, Well-drained soil, limited irrigation water.
VI, VII, and VIII, Huntley project lands.
IX, Dry-land, single species.

they are not. Some deep productive soils formerly giving no responses to phosphates are, after years of cropping, beginning to do so. In Cache Valley, Utah, for example, phosphates and manure have brought increased yields of 45 to 95 per cent and have increased the proportion of legumes (Bateman, 1943*b*, and Utah Station, 1943). After they are well started, pasture grasses respond readily to top-dressings of farm manure in which the liquid fraction has been preserved. From 100 to 300 pounds of ammonium sulfate usually increases grass growth but will probably not materially affect the legumes.

No State has recorded any response to potassic fertilizers, except in limited areas of peat soils (Bateman, 1943*a*, *b*; Peterson, 1943; and Pittman and Thorne, 1941).

Seed-bed and seeding. All agencies agree (see most articles in Bibliography) that, within the economic limitations involved, seed-beds should be well-prepared, firm beneath but soft and mellow for one-half to 1 inch on the surface; that high quality well-chosen seed should be used; that seeds should be evenly distributed and covered with one-half to 1 inch of soil; that seeding should

TABLE 5

Recommended Seed Mixtures for Irrigated Pastures in Wyoming (Boyd, 1940) and Colorado (Robertson, Weihing and Stewart, 1942)—pounds per Acre

Species	Wyoming—1943					Colorado—1943			
	I	II	III	IV [1]	V [2]	VI	VII	VIII [1]	IX [2]
Smooth brome	9	5		6	3	8		6	3
Meadow fescue	5	3			4	6		2	3
Orchard grass	9	5		2		8			
Perennial ryegrass					3	(4)			4
Crested wheatgrass		7		4				4	
Timothy	4		6			(4)	6		
Slender wheatgrass				4				4	
Redtop			6				10		
Reed canary grass					3		4		4
Yellow sweet clover	3	4		2	3	2		2	2
White clover					2	(2)			
Red clover						(2)			
Alsike clover			3				2		2
Strawberry clover					2				2
Alfalfa				2			2	2	
Total	30	24	15	20	20	36	24	20	20

[1] From Forest and Range Experiment Station trials.
[2] This class not dealt with in State reports; drawn from trials in nearby parts of Idaho and Utah.

Wyoming:
I and II, Good soil, well-drained.
III, Wet land.
IV, Porous soils, limited irrigation.
V, Soil partly waterlogged, considerable alkali.

Colorado:
VI, Good soil, well-drained.
VII, Soil poorly drained.
VIII, Porous soils, limited irrigation.
IX, Soil partly waterlogged, considerale alkali.

be done just before the most prolonged moist period of weather; that new seedings should be kept uniformly but not excessively wetted; and that grazing should not begin until the stand is well established and should then be moderate and probably so rotated with reference to the early spring period that repeated close early utilization will not result.

To designate the desirable conditions rather than the particular means of achieving them is the important thing. For example, drilling in undisturbed grain stubble may often satisfy seed-bed and seeding requirements; sometimes broadcasting and harrowing are suitable where drilling is not feasible. The most effective method of irrigation is likely to be the one locally best understood. Moderately frequent and fairly uniform wettings are essential. Over-saturation is likely to be damaging to soil structure and to the plant habitat as all species except redtop and reed canary grass do best on well-

TABLE 6

Recommended Seed Mixtures for Irrigated Pastures—Arizona (Matlock, 1943) and New Mexico (Stroud, 1943)—Pounds per Acre

Species	Arizona—1943				New Mexico—1943		
	I	II	III	IV	V	VI	VII
Smooth brome		3	4	5	4		5-7
Orchard grass	4	2	3		4-8		
Meadow fescue	6	6	6	3	4-8	6-8	
Dallis grass	6	6					
Rhodes grass	2	2					
Perennial ryegrass	4	4	6	4	4	4	
Kentucky bluegrass				2			
Crested wheatgrass				5			
Reed canary grass						6-8	
Ladino clover					3-4		
Alfalfa	2	3	3	2	some	some	8
Bur clover	2	2	2				
Strawberry clover						3-4	
Hubam sweet clover	2						
Yellow sweet clover		2	3	2	2	2	
Red or alsike clover				2			
Total	28	30	27	25	21-30	21-26	13-15

Arizona:
I, Good irrigated lands below 2000 feet elevation.
II, Good irrigated lands, 2000-3600 feet elevation.
III, Good irrigated lands, 3600-5000 feet.
IV, Good irrigated lands, above 5000 feet.

New Mexico:
V, Good soil, good drainage, middle Rio Grande Valley.
VI, Alkali land, Rio Grande Valley.
VII, Good soil, irrigation limited or precipitation good.

drained, moist soils. Most of them endure moderate soil alkali; strawberry clover and Rhodes grass are noteworthy in their ability to withstand soil alkali.

Sowing pastures with small grain crops is in much less favor now than it was a few years ago. It has been found that too heavy stands of grain tend to smother the pasture plants. All stations favor early spring seeding, either

with no companion crop, or with one that does not produce heavy shade, or with one that is removed early, before maturity if necessary, to protect the pasture seedlings. Consensus has thus grown to regard the pasture stand as a primary instead of a secondary consideration. In the mountain region surveys show about one-third of the pastures are seeded in spring with small grains, about one-third in spring alone, and one-fourth in late summer after crops are removed. In the hot country fall seeding is almost universal. Some returns from a companion crop will probably be sought under extensive farming,

TABLE 7

Recommended Seed Mixtures for Irrigated Pastures—California (Jones and Brown, 1942) By Counties in Representative Parts of the State [1]

Species	Seeds—pounds per acre—1942											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Domestic ryegrass			4	5	2	4	3	8	1	4		3
Orchard grass	6	4	(4)	5	4	4	3	4	3			
Dallis grass			4	(5)		4			3	6	4	2
Harding grass		2			2	(2)		4				
Perennial ryegrass	5	8							3			
Rhodes grass											6	4
Meadow fescue	6				2	(2)			3			
Tall oat grass							3					
Ladino clover		4	4	4	3	4	4	4	3			
Alfalfa			2		(2)	3	2	4		5		4
Bur clover						3	3		3	4		
Red clover	2											
Alsike clover	2					(1)						
Yellow sweet clover											6	3
Strawberry clover											4	2
Total	21	18	14	14	13	22	18	24	19	19	20	18

[1] California Extension Service made recommendations for nearly all counties from which these are selected.

Good soil well irrigated by counties:

I, Modoc.
II, Mendocino.
III, Sutter.
IV, Sacramento.
V, San Joaquin.
VI, Fresno.
VII, Monterey.
VIII, Ventura.
IX, Riverside.
X, Palo Verde and Coachella Valleys.
XI, Alkali land, Orange Co.
XII, Alkali land, Madera Co.

but this practice is expected to decrease as agriculture in the area becomes more fully developed. Late summer seeding requires ample water for late irrigation.

Early management. It is generally recommended (see most articles in Bibliography) that young pasture stands be kept moist, that they be top-dressed with 5 to 10 tons of manure annually, and grazed moderately. Weed growth needs to be mowed, and manure droppings scattered after irrigation by means of a heavy chain drag or with a non-rigid harrow that will bend down into

low places, similar to the Australian pasture harrow. It is well to have the pasture in two or three fields so as to practice rotation of grazing use, in order not to graze early each spring on the same pasture and to avoid grazing immediately after irrigation. Ponding of water should be corrected, since this favors low-value, water-loving grasses or sedges and rushes.

Manuring, irrigation and light grazing promote a rapid growth of grasses which tend to suppress the legumes by shading. An occasional close grazing or mowing, or both, will help to preserve the mixed population. Close observation shows that pasture plant population is dynamic, with short-lived species abundant at first, after which slower-growing species predominate in the sward. An important element in preserving the mixture is the type of management that at some period of the season favors tall grasses, short grasses and legumes. Bateman at the Utah Station (Bateman, 1943*a*, and Utah Station, 1943) preserved the desirable mixtures for 10 or more years by manuring, harrowing, heavy close grazing for a few days, followed by removal of the cows to other pastures. After an interval of 3 to 6 weeks the cows completed the rotation and again grazed in the field used first. The pastures were harrowed after irrigation, and old stems or weeds were clipped once or twice during the season. The pastures were grazed very early in spring, not more often than once in every fourth year. Bateman also favors night as well as day pasturing, as this materially increases the manure droppings especially when high-producing dairy cows are fed some grain, as is commonly recommended.

Dry-Farm Pastures

In the mountain and plateau region dry-farming has been developed on good soils where the precipitation is favorable. Where livestock growing constitutes a major agricultural enterprise in the economy of a group of communities, dry-farm pastures properly receive consideration as one means of tiding over periods of feed shortages, generally in the spring of the year after animals are removed from irrigated lands and before the forages on high summer ranges are ready to be grazed. Utah, Idaho, Montana and Colorado have made recommendations as to mixtures suitable for this purpose, which are given in Table 8. The other States undoubtedly have at least started to wrestle with this problem, but no applicable information was found in their publications or letters answering inquiries. The table shows that a leguminous species is in most cases included in the suggested mixture. Probably 1 or 2 pounds of alfalfa seed per acre should be included in the ordinary dry-farm pastures in Utah.

Mixtures are definitely favored over single species, seed-beds firm beneath but mellow on top are advocated, seeding with a drill is preferred, no fertilizers are recommended and companion (nurse) crops are not even mentioned. Fall seeding is almost universally recommended except where summer rains are common, as is also little or no grazing the first year after seeding. Short-time crops of single species such as rye, sweet clover, Sudan grass or sorghums are suggested for " quick " feed. When it is time for grazing to begin, all agencies dealing with the problem favor moderate grazing, rotated in such a manner that the same pasture does not receive early use year after year. Wide fluctuations

in precipitation naturally bring about wide variations in forage production. During dry years precautions are necessary to avoid severe overgrazing. Established dry-farm pastures may be maintained for long periods provided they are grazed moderately and otherwise properly managed. Under such conditions soil conservation is also achieved.

TABLE 8

Recommended or Suggested Seed Mixtures for Dry-farm Pastures in Utah (Bracken and Evans, 1943, and Plummer, Hurd and Pearse, 1943), Idaho (Hull and Pearse, 1943), Montana (Williams and Post, 1941, and Williams, 1943), and Colorado (Nelson and Shepherd, 1940)—Pounds per Acre

Species	Utah—1943		Idaho—1943		Montana—1936			Colorado—1940		
	I	II	III	IV	V	VI	VII	VIII	IX	X
Crested wheatgrass	4	6	5	4	5	6		5		8
Western wheatgrass	2	2	2					3		
Slender wheatgrass	2			2					5	
Smooth brome	3			2			8	4	10	10
Orchard grass										8
Bulbous bluegrass		1	1							
Meadow fescue				x [1]					x [1]	x [1]
Tall oat grass				x [1]					x [1]	x [1]
Alfalfa		2	2		5					
Yellow sweet clover				2		4	4	2	2	4
Total	11	11	10	10	10	10	12	14	17	30

[1] Check marks (x) indicate species recommended but not included in mixture named.

Utah:

I, Ordinary dry-farm conditions.
II, Favorable conditions, deep porous soil.

Idaho:

III, Ordinary dry-farm lands, up to 5000 feet.
IV, Better dry-farm lands 5000 to 7000 feet.

Montana:

V, VI, and VII, Conditions similar to Judith Basin or in southwest corner of State.

Colorado:

VIII, Dry foothill valleys, east slope.
IX, Mountainous valleys, east slope.
X, Mountainous valleys, west slope.

RESEEDED RANGE LANDS

Since 1926 investigations of reseeding on range lands have been conducted in central Utah by the Intermountain Forest and Range Experiment Station (Stewart, Walker and Price, 1939). In 1935 this study gained substantial financial support and was organized into a systematic program in Idaho and Nevada, as well as in Utah, where the Soil Conservation Service, the Bureau of Plant Industry, the Grazing Service, and the State Experiment Stations and Extension Services have taken much interest. All together more than 300 forage species have been tested for suitability to site and climatic conditions at various elevations. Alfalfa, sweet clover, common clovers, and

a number of other legumes obtained from Soil Conservation nurseries have been included. As yet no legume has been found that becomes an enduring part of

TABLE 9

Recommended Seed Mixtures for reseeding Range Lands in Nevada, Utah, and Southern Idaho (*Hull and Pearse*, 1943; *Plummer, Hurd and Pearse*, 1943; *Robertson and Pearse*, 1943; *and Stewart, Walker and Price*, 1939)

Intermountain Forest and Range Experiment Station—1943

Species	Pounds per acre									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Crested wheatgrass	4-8	3-5	2	3				3	2	
Western wheatgrass		4-6		2						
Slender wheatgrass					2	3	2		2	2
Orchard grass						2	1		1	2
Big bluegrass								1		
Bulbous bluegrass	1							2		
Smooth brome			4	3	4	4	4	2	3	4
Tall oat grass			4	2	2	3	2	(2)	(4)	
Meadow fescue			3							
Perennial ryegrass			3							
Mountain brome					2	6	2	3	4	4
Timothy						2	1			2
Kentucky bluegrass							1			
Yellow sweet clover			2							
Total	5-9	7-11	18	10	10	20	13	11	12	14

I, Dry valleys, 10 to 14 inches precipitation.
II, Same, heavy soil.
III, Same, saltgrass (moderate alkali) lands.
IV, Foothill lands (mountain brush), dry sites, 12 to 18 inches.
V, Same, moderately moist sites.
VI, Open aspen stands 20 to 30 inches.
VII, Subalpine ranges, weedy, 25 to 40 inches.
VIII, Mountain brush, southeastern Idaho.
IX, Mountain valleys, Idaho, dry sites.
X, Recently burned timber land, Idaho.

the plan except in special sites. About a dozen grasses have proved suitable (Hull and Pearse, 1943; Plummer, Hurd and Pearse, 1943; Robertson and Pearse, 1943; and Stewart, Walker and Price, 1939) and are the principal members of seed mixtures recommended. On hot, dry sites, crested wheatgrass has been found superior to all others, perhaps on account of its rapid root development (Plummer, 1943). Meantime the search for suitable legumes is being continued and breeding to improve grasses is in progress (Keller, 1941). Enough information has been collected to establish a program for seeding under ten major ecological situations, for which recommended seed mixtures are presented in Table 9.

The New Mexico Station (Bridges, 1942) has, as a result of its investigations, recommended the mixtures shown in Table 10. The Northern Rocky Mountain

Forest and Range Experiment Station suggests mixtures in Montana (Hurtt, 1943, and Short, 1943) which are also shown in Table 10.

TABLE 10

Recommended Seed Mixtures for reseeding Range Lands in Montana (Hurtt, 1943, and Short, 1943) and New Mexico (Bridges, 1942, and Parker and McGinnies, 1940), and Species suitable for Wyoming (Wyoming A.E.S., 1942)

Species	Pounds per acre							
	Montana—1943		New Mexico—1940					Wyoming
	I	II	III	IV	V	VI	VII	VIII
Crested wheatgrass	4	2		3	3	4	5	x [1]
Western wheatgrass				5	5	3	4	
Slender wheatgrass		2						
Smooth brome		4				6	6	x
Tall oat grass		2						
Blue grama					4			x
Rothrock grama			4					
Lehmann lovegrass			½					
Boer lovegrass			½					
Sand dropseed			1	½				
Green needlegrass								x
Galleta grass				5	5			
Russian wildrye								x
Alfalfa		2						x
Yellow sweet clover	1					3		
Total	5	12	6	13½	17	16	15	

[1] Check marks (x) indicate species recommended but with mixture not named nor amounts of seed specified.

Montana:
I, Dry foothills and mountain valleys.
II, Mountains, moist sites.
New Mexico:
III, Southwestern semidesert, precipitation 8 to 10 inches.
IV, West central plateau, 5500 to 7200 feet, precipitation 12 to 18 inches.
V, Northwestern semidesert, 4500 to 7200 feet, precipitation 7 to 15 inches.
VI, High mountains, 7200 to 13,000 feet, precipitation 20 to 30 inches.
VII, Northern foothills, 7200 to 8500 feet, precipitation 15 to 20 inches.
Wyoming:
VIII, At Lyman, Church Buttes grazing area, about 7000 feet, precipitation about 13 inches, species named in a mixture giving high yields, no recommendation made.

Because range reseeding in other States is newer and has been less adequately supported financially, information regarding mixtures is less complete. Nearly every station lists suitable species and says mixtures are desirable, but does not name mixture components either in publications or in reply to letters. Legumes are generally listed, but it is not known whether more intensive tests will largely eliminate them as happened in Utah, Idaho and Nevada, where in the early years they were also listed. The status of

information in Wyoming, Colorado, Arizona and California, so far as it could be found at the present writing, is shown in Tables 10 and 11.

TABLE 11

Species recommended for reseeding Range Lands in Colorado (Nelson and Shepherd, 1940), Arizona (Flory and Marshall, 1942, and Parker and McGinnies, 1940), and California (Jones, 1942, and Talbot, 1943)—Mixtures recommended but no Components given

Species	Colorado—1940-42				Arizona—1940			California—1942-43		
	I	II	III	IV	V	VI	VII	VIII	IX	X
Crested wheatgrass	x		x				x			x
Western wheatgrass	x		x		x				x	
Slender wheatgrass	x	x		x	x		x			x
Smooth brome	x	x		x			x			x
Mountain brome		x		x			x			x
Tall oat grass				x			x			x
Galleta grass			x		x	x				
Indian ricegrass			x		x	x				
Domestic ryegrass								x	x	
Perennial ryegrass									x	
Harding grass								x		
Buffalo grass	x					x				
Wimmera ryegrass										x
Weeping lovegrass						x		x	x	
Tanglehead						x		x		
Blue grama	x				x					
Rothrock grama						x				
Tobosa						x				
Bur clover									x	
Alfalfa		x	x		x				x	x
Yellow sweet clover	x			x			x			x
Subterranean clover								x	x	
Alfileria						x		x		
Burnet								x		

Colorado:
I, Foothill zone.
II, Mountain zone.
III, Dry foothills and valleys.
IV, Aspen zone, western slope.

Arizona:
V, Plateau zone, 5000 to 8000 feet.
VI, Hot country, below 5000 feet.
VII, High plateau and mountain zone, northern part.

California:
VIII, Low, hot country.
IX, Interior valley edges and foothills.
X, Mountainous zone.

Research on range reseeding has passed the exploratory phases in Nevada, Utah and Idaho, and is settling down to definite investigations as to how to handle specific problems. In Montana, Colorado and New Mexico it is newer but has made great progress, whereas in Wyoming, Arizona and California it has just begun or is still contending with the broader phases of species adaptation. Findings of the Intermountain Forest and Range Experiment Station for Nevada, Utah and Idaho are with necessary modifications being partly accepted in the other States.

In general terms the principal features of a program have been set up, limiting recommendations to the more favorable site conditions, since these

offer promise of surest returns and since research has not yet made an organized attack in the zones having most severe conditions of climate and soil (Stewart, Walker and Price, 1939). For the more favorable conditions it has been found that a few species with commercially available seed, and a few other species not yet commercially available, are suited for reseeding; and that mixed seedings are to be recommended, although fully suitable legumes have not yet been found. Fall seeding is favored except in a few localities having dependable spring or summer rains (Stewart, 1938). Generally it is too expensive to prepare a seed-bed on range lands. Preliminary tests with phosphatic and nitrogenous fertilizers are inconclusive. Recommendations for these two fertilizers are therefore omitted until evidence of value appears.

Seed should always be covered with soil (Hull and Pearse, 1943; Hurtt, 1943; Plummer, Hurd and Pearse, 1943; and Robertson and Pearse, 1943). This may be accomplished by drilling, harrowing or brush-dragging. A disk grain drill has been found to be very effective where its use is feasible. Some soils when plowed are sufficiently loose to cover seed by sloughing. Where heavy stands of sagebrush occur (Stewart, 1938), they need to be removed before seeding by railing, disking with wheatland "plow," or burning. It seems best to space seeded drill rows 12 to 24 inches apart rather than closer or farther apart (Hull and Pearse, 1943; Plummer, Hurd and Pearse, 1943; Robertson and Pearse, 1943; and Colorado A.E.S., 1941-42). Some workers favor light seeding rates to reduce seed cost, but some think experience warrants heavier seeding rates; for example, the Colorado Station reports a 20 per cent increase in yield for 12-pound as compared with 4-pound seeding (Colorado A.E.S., 1941-42). Drilling among Russian thistle has proved successful but in cheatgrass (*Bromus tectorum*) stands some means of disturbing cheatgrass before, or at, seeding time is required. Furrow drilling and disk-tiller drilling have been used successfully in a number of cases. Although failures with range reseeding have to be expected in unfavorable seasons, reports from national forests in Nevada, Utah and Idaho indicate that where recommendations are followed, about 70 per cent of the seedings were successful. A few other seedings, thought at first to be failures have, after 3 or 4 years, proved at least partly successful.

Range seedings need to be protected against grazing until the stands are established (see General Literature) which is generally 12 to 18 months after seeding. Subsequent grazing must be at moderate intensity and otherwise properly managed in order to prevent stands from becoming weakened, or killed under severe misuse.

Hay Mixtures

Hay in the Intermountain and South Pacific Coast area is predominantly straight alfalfa and wild-hay grasses. The latter grow in natural meadows and are practically never seeded artificially. The 1940 census reports only about 726,000 tons of clover and timothy hay (5·1 per cent of the total) and 337,000 tons of other tame hay (2·4 per cent), much of which is not mixed. At most, about 5 per cent and probably less of the hay grown falls into the class of mixed seedings, nearly all of which is timothy and red or alsike clover, with alsike generally preferred. High irrigated valleys in Idaho, Montana,

Wyoming and Colorado grow about 85 per cent of the mixed hay produced in the area.

Timothy and clover are ordinarily spring-seeded in amounts of around 8 to 12 pounds of timothy and 3 to 6 pounds of clover per acre, on land too damp and cool for alfalfa, which would otherwise occupy much of the acreage (Robertson, Weihing and Stewart, 1942, and Williams, 1943). It is drilled in spring on firm, moist seed-beds and usually clipped high late in the season, largely to control weeds. It is ready for hay with some aftermath pasturage in the second year.

Considerable experimentation and practical growing tests have been made with grass and alfalfa hay mixtures. Hay production in many cases has been decreased (Weihing and Koonce, 1942) in both yield and quality, although increased yields have been obtained in Montana (Williams, 1943). The reduced quality is caused by the low protein and mineral content of the grasses in the first cutting, and the low yields by the small regrowth of grasses for later cuttings and low volume of alfalfa due to the thin stand of that species (Piper, 1924, and Weihing and Koonce, 1942).

On land too moist for alfalfa, tame grasses produce about 2 per cent of the hay crop. These grasses are generally spring-seeded. The most common grasses grown alone or in mixtures are timothy, smooth brome, meadow fescue and orchard grass, with some slender and crested wheatgrasses in the drier places. Such grasses are not ordinarily cut in the first year except to clip back weeds.

Mixed wild grasses, sedges and rushes produce about 12 to 13 per cent of the hay, but, as they form natural meadows, there is no establishment problem. Another 8 to 9 per cent of the hay is from small grains cut green, largely in California, which produces more than 60 per cent of all that is grown in the area. Neither wild hay nor small grains come within the scope of this symposium.

An almost negligible amount of mixed pea-oat hay is grown on moist land, largely when alfalfa stands winter-kill, or as an emergency annual crop. Spring seeding on seed-beds prepared as for small grains, with a bushel of peas and 60 to 80 pounds of oats to the acre is common practice.

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UNITED STATES OF AMERICA

Pacific Northwest Region

The Pacific Northwest region of the United States has certain characteristics that differentiate it rather distinctly from any other region in the country. The climate in general is mild but becomes progressively more severe from the coast inland so far as temperatures are concerned. Rainfall varies from over 100 inches to less than 10 inches annually. The heavier rainfall areas are for the most part in the coastal sections and higher interior altitudes. The altitude of agricultural lands varies from practically sea-level to between 4000 and 5000 feet elevation, with the topography from relatively level or gently rolling to rather steep. Certain areas used for summer grazing occur at altitudes as high as 9000 feet.

Soil types are extremely variable, not only as to origin, character and fertility, but also utility. Most areas originally or at present supporting heavy growths of vegetation lend themselves well to cultivation providing they are accessible and have a topography such that they can be cultivated.

This region may well be divided into three agricultural sections :—

(*a*) humid coastal, or the section between the Pacific Ocean and the Coast Range mountains ;

(*b*) sub-humid valleys, or the area between the Coast Range and Cascade Mountains ; and

(*c*) the intermountain section between the Cascade Mountains and the western slope of the Rocky Mountains.

The coastal area was for the most part originally covered with an exceedingly heavy growth of coniferous timber at practically all elevations. Only in a few instances did small open prairies, covered with low growth, mostly grass, occur.

The area between the Coast Range Mountains and Cascade Mountains was partially covered with timber originally. The timber was mostly evergreen but here and there interspersed with various deciduous species. In this area, particularly on certain of the valley floors, there occurred a rather large acreage of open lands covered with heavy growths of grass and legumes, interspersed with brush and small deciduous trees.

In the section between the Cascade Mountains and Rocky Mountains the higher elevations were covered with evergreen timber where rainfall and soil were sufficient to support such growth. Other areas, constituting the major portion, were covered with native dry-land and semi-dry-land grasses and other miscellaneous plants, including certain shrubs.

In the coastal section the present cultivated lands are for the most part the result of cutting over and clearing. This is the situation also for the area between the Coast Range and Cascade Mountains except for the original open lands. In the section between the Cascade Mountains and Rocky Mountains most of the present cultivated land is the result of the breaking up of the bunchgrass and sagebrush lands. In this section considerable land is under irrigation. The unirrigated land in areas having an annual rainfall of 20 inches or less is mostly farmed by the summer-fallow method. This results

Fig. 84.—Dairy cows pasturing on new stand of Alta fescue in area between Coast Range Mountains and Cascade Mountains of Pacific Northwest, U.S.A.

Fig. 85. Aftermath of Alta fescue harvested for hay after seed crop has been removed. Regrowth will produce abundant late summer and fall pasture. Dual utility practiced in area between Coast Range Mountains and Cascade Mountains of Pacific Northwest, U.S.A.

Fig. 86.—Suffolk and Hampshire lambs wintered on Alta fescue pasture with no supplementary feed in Western Oregon, U.S.A.

Fig. 87.—Dairy cattle pasturing on alfalfa. A common practice in the Pacific Northwest, U.S.A.

Fig. 88.—Dairy cattle pasturing on Kentucky bluegrass and alfalfa in higher altitude irrigated sections of region between Cascade Mountains and western slope of Rocky Mountains of Pacific Northwest, U.S.A.

Fig. 89. Excellent fall burn on logged-off land in Pacific Northwest, U.S.A. Seeded immediately after burn and excellent stand secured. Picture taken first spring following fall burn.

Fig. 90.—Same as Fig. 89, except that the amount of debris is larger. Background seeded. Foreground not seeded.

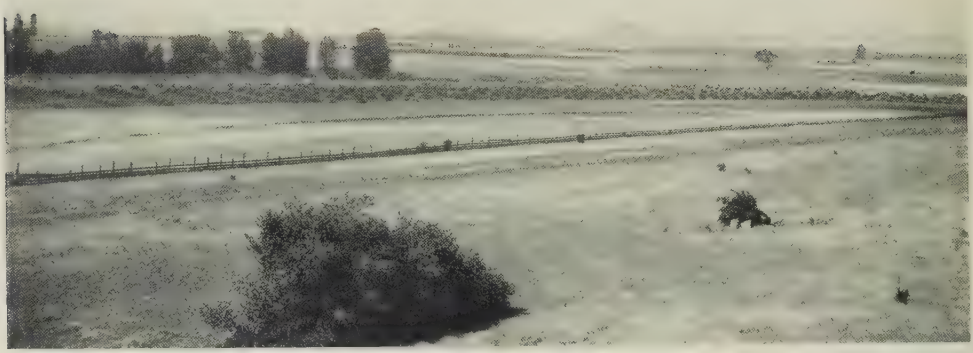

Fig. 91.—Typical Pacific Northwest, U.S.A., humid section area used for crop and pasture production. Pasture improvement on this land is progressing rapidly.

Fig. 92.—Hay, grain, and mountain range land in intermountain region of Pacific Northwest, U.S.A. This is typical of large areas used for cattle, sheep, and horse production.

Fig. 93.—Natural mountain meadow in intermountain region of Pacific Northwest, U.S.A. It is such meadows as these on which the cattle industry depends to a considerable extent for summer forage. Many of them are badly over-grazed. Some are being reseeded.

in conservation of soil moisture to the extent that enough moisture is available every other year, by saving the major portion of that of the previous year for the production of a cultivated crop.

In the coastal section there has been considerable reclamation of tide lands by diking and draining. In the section between the Cascade Mountains and Rocky Mountains, particularly where irrigation farming is practiced, considerable areas of alkaline soil occur. These two conditions are factors in grass or grass-legume land agriculture.

Coastal Section

Low and Tidelands

Types of mixtures for grass and grass-legume land agriculture are extremely variable in this section. On the bottom lands, either diked or undiked, where soil moisture supplies are practically always plentiful, soil fertility comparatively high, pasturing possible for the major portion of the year, and conditions for preserving harvested forage rather adverse, it is of necessity desirable that plantings of a permanent nature be made. Such plantings should consist of long-lived adapted perennial grasses and legumes. Suitable grasses are comparatively numerous; the securing of long-lived perennial legumes has been considerably more difficult and the species are few.

At present practically all the native grasses and legumes once prevailing in this section have been destroyed or superseded by imported species. On such lands where plantings are made there is generally a natural semi-occupancy of imported grasses including either seaside bent (*Agrostis palustris*), Astoria bent (*Agrostis tenuis* var. *astoriana*), redtop (*Agrostis alba*), and velvet grass (*Notholcus lanatus*), with white clover (*Trifolium repens*).

Long-lived mixtures on this type of land are generally constituted so as to include perennial ryegrass, orchard grass, timothy, Alta fescue (*Festuca elatior arundinacea*), white clover, birdsfoot trefoil (*Lotus corniculatus*), or big trefoil (*Lotus uliginosus*). On lands that are very high in acidity, which is quite common in the coastal section, alsike clover and white clover are often used in combination with grasses. On lands that are inclined to be very wet and possibly subject to periodic overflow, reed canary grass (*Phalaris arundinacea*), meadow foxtail (*Alopecurus pratensis*), and either seaside bent or Astoria bent are used. The possibility of using a legume under these conditions depends altogether on the length of time of overflow and whether or not the overflow water is brackish. On the lower or diked lands, seed-bed preparation is either as the result of burning over after timber removal or mechanical cultivation after most or all of the timber has been removed.

Uplands

On the coastal hill lands from which the timber has been removed a very distinct and separate problem in developing permanent grass or grass-legume land agriculture occurs. It is necessary, or at least very desirable, to remove from this land, after logging operations, as much of the debris as possible. This is for the most part done by burning immediately after or within two years after completion of logging operations. The most desirable time to

establish seedings on such lands is immediately after burning, with fall seedings preferred to those made in the spring. It is particularly desirable to seed permanent soil cover plants of high economic value. These lands in general are acid, only medium in fertility, and comparatively rough. Their moisture holding capacity is fair. Sod-formers are particularly desirable on such land, not only to provide forage, but also to prevent erosion and inroads of weeds, moss and brush. It is usually expected that when once an area of this land is sown, seeding is to be permanent, as reseeding is extremely difficult and in many places practically impossible.

Seeding mixtures on such lands generally include perennial ryegrass, orchard grass, Alta fescue, chewings or creeping red fescue, and Astoria bent or Highland bent in combination with white clover, subterranean clover, big trefoil or birdsfoot trefoil.

Nurse crops are occasionally used on the bottom lands, such nurse crops usually being a cereal, either winter or spring, depending on time of seeding.

Temporary grass or grass-legume seedings are occasionally made on cultivated bottom and uplands where short-time rotations are followed. Such rotations generally include grass or grass and legume mixtures and roots. Cereals, especially oats, are often seeded.

Fall seedings are always desirable regardless of the type of land or its location, unless the particular place has some natural handicap such as excessively severe winters following very soon after the seeding season or is subject to inundation. Spring seedings are quite often made, however, with their success depending on summer soil moisture.

Seed-bed preparation under any conditions other than by burning of cut-over lands is dependent on the type of land, freedom from obstructions such as stumps, logs and debris, and the equipment available.

Method of seeding is either with machinery or broadcasting by hand or with hand equipment. On cultivated lands power or horse-drawn machinery can be used for seeding. On rough and logged-off lands hand broadcast seeding is the most common method. Seedings by airplane have been made with reasonable success on large areas when efficient personel and equipment have been available and atmospheric conditions favorable for uniform seed distribution.

Grazing management of fall seedings should be such that livestock are kept off the new seedings until they are well established, which is usually early May to early June. Spring seedings are generally in condition for utilization after fall rains have stimulated plant growth.

For the making of grass-legume seedings on upland cultivated areas the practice is to prepare the seed-bed in the best possible manner, and to seed in the early fall or very early spring with grasses and legumes according to the anticipated length of life of the area from the utility standpoint, using mechanical equipment wherever possible and delaying utility until the plants are well established or ready to harvest.

The rates of seeding for the various type areas are dependent on soil, moisture, constitution of the seeding, and actual area seeded. This last point is quite important, especially on cut-over lands where under some conditions as much as 30 to 40 per cent of the area may be covered with stumps and logs.

In this section irrigation in the commonly accepted sense is not possible except under certain specific instances. Supplemental irrigation by sprinkling is increasing and is the most economical and feasible method.

On very wet or overflow lands very early spring seedings are most desirable, with very early fall seedings next in preference where the land can be prepared for seeding and the seeding actually accomplished. Fall seedings are usually jeopardized by early floods. Spring seedings are occasionally in jeopardy when seeded late and followed by lack of soil moisture.

Section between the Coast Range and Cascade Mountains

This section in general is characterized by rather plentiful supplies of winter moisture, practically all in the form of rain, and by rather dry summers extending from June to mid-September.

From the area production standpoints as pertaining to grass and the grass-legume production, it includes river bottoms, upland or first bench and hill lands.

The river bottom lands are for the most part rather intensively cultivated, with production depending on the particular soil type. Most of these areas are of a sandy or silty loam character, have good drainage, reasonably good moisture-holding capacity and fair fertility. Wherever alfalfa can be grown its production is desirable. Most alfalfa seedings are made alone in the spring on well-prepared seed-beds at the rate of 10 to 12 pounds an acre. No nurse crops are ordinarily used unless irrigation is available. Recent practices indicate the desirability of inter-seeding during the fall of the first year with such grasses as orchard grass, tall meadow oat grass (*Arrhenatherum elatius*), perennial ryegrass or Alta fescue. Fair stands of grass are usually secured and the growth is satisfactory. By the introduction of cultivated grasses, weedy grasses and weeds are usually either eliminated or very much reduced in population. The rate of seeding of grasses is approximately one-half that used for normal straight seedings.

These river bottom lands produce excellent growths of such grasses as perennial ryegrass, orchard grass, tall meadow oat grass, Alta fescue, chewings fescue (*Festuca rubra commutata*), and creeping red fescue (*Festuca rubra stolonifera*). Timothy and Kentucky bluegrass are occasionally seeded but are seldom as successful as the other grasses mentioned. Legumes under these conditions include, other than alfalfa, red clover, white clover and subterranean clover. Considerable irrigation is practiced on these lands either by furrow or flooding or sprinkling, and under such conditions the grasses mentioned are satisfactory as are also the legumes. Additional legumes of value include Ladino clover (*Trifolium repens* var. *latum*) and birdsfoot and big trefoil.

Temporary or short-lived grass-legume plantings include sweet clover or crimson clover (*Trifolium incarnatum*), combined with perennial ryegrass, Sudan grass (*Sorghum vulgare* var. *sudanense*), with red or crimson clover and vetches, combined with winter cereals.

Of the first series of uplands, quite commonly referred to as first bench lands, two types of mixtures are desirable: (*a*) long-lived, (*b*) short-lived or temporary. For long-lived mixtures such grasses as perennial ryegrass,

orchard grass, Alta fescue, chewings or creeping red fescue, Highland bent, and tall meadow oat grass are desirable. As to whether or not a legume should be included depends altogether on the type of soil, its summer moisture-holding capacity, and its fertility. Generally, legumes are a minor factor under such conditions because they have extreme difficulty in persisting during the summer. Subterranean clover seems to be one of the most satisfactory at this time because of its non-summer-growing and early maturity habit. Where irrigation is available, any of the longer-lived clovers and in many instances alfalfa can be used satisfactorily.

On the heavier, shallow, poorly drained, low-fertility soil types in the bench land areas, permanent seedings, unless under irrigation, are constituted almost altogether of grasses that are relatively deep-rooted so as to be able to secure summer moisture supplies and still be of such a character that they can withstand excessive soil moisture during the winter. Such grasses include perennial ryegrass, Alta fescue and Highland bent.

For temporary pastures, common ryegrass is generally used. Sudan grass is also used and on better drained areas vetches and cereals are useful, either alone or in combination.

The hill-land areas in this section are very similar to those in the coastal section and the same conditions in general prevail as to types of seedings, date, rate, and methods of seeding and seed-bed preparation.

Velvet grass occurs abundantly throughout this whole section. It is found on all types of soil regardless of conditions and, while generally not considered as a too satisfactory plant, nevertheless has considerable value because of its wide adaptability.

The early management of any seeding in this section depends on climatic and soil conditions and from the temporary utility standpoint should be such as to secure full value from the seedings without abusing the soil. Permanent seeding management should be such that the plants are given full opportunity to become well established before the initial utility period.

Seeding rates in this section are dependent almost entirely on soil types, soil moisture, species seeded and utility. Blanket recommendations either as to species or rates are generally not advised because of the extremely variable conditions existing.

Section between Cascade and Western Rocky Mountains

This section contains the largest areas of irrigated lands in the Pacific Northwest. These are of rather high fertility and grow a wide range of grass and legume species. The primary grasses include smooth brome (*Bromus inermis*), Kentucky bluegrass, timothy, orchard, tall meadow oat, and Alta, meadow, chewings and red creeping fescues. The legumes include alfalfa, red, white, alsike, Ladino, sweet and strawberry (*Trifolium fragiferum*) clovers, birdsfoot and big trefoil, vetches and peas. The vetches and peas usually lack winter hardiness and are generally spring-seeded. In addition to the perennial grasses mentioned, winter or spring cereals are satisfactory from the temporary standpoint.

Seedings on these irrigated lands are usually made in the spring on well-prepared seed-beds. Proper seed-bed preparation is very desirable so as to

facilitate irrigation and harvesting. Seeding is practically all done with machinery.

Early management of the sward under these conditions depends entirely on plant growth and the type of utility. Nurse crops can be used satisfactorily under these conditions providing moisture supplies are adequate.

Under irrigated conditions in this section difficulties with alkalinity are often encountered. On such soils Kentucky bluegrass is reasonably satisfactory providing the pH is not too high. Strawberry clover, sweet clover, birdsfoot trefoil and big trefoil are the most adaptable legumes.

By far the largest area of cultivated lands in this section are cultivated and cropped on the so-called dry-farm basis. Where the annual precipitation is 20 inches or more per year, with fairly even distribution, production of field crops is to a considerable extent on a continuous annual basis. Where the precipitation is below 20 inches, alternate-year cropping with a summer fallow year interposed is the general agricultural practice. Under a few very low rainfall conditions, production is occasionally on a two-year fallow and one-year crop basis. Such lands, however, are considered as submarginal and their cultivation is discouraged. They are much better suited for grazing purposes.

In the 20-inch or more rainfall areas a number of grasses can be successfully grown. The relatively permanent ones include crested wheatgrass (*Agropyron cristatum*), western wheatgrass (*Agropyron smithii*), slender wheatgrass (*Agropyron pauciflorum*), smooth brome grass, and big bluegrass (*Poa ampla*). Native bunch grasses (*Agropyron*, *Poa*, *Festuca* and *Bromus* species) are also very satisfactory under these conditions but are as yet seldom seeded. It is these grasses, and particularly the *Agropyron* species, that constituted most of the grass population over this section at one time. Most of them have been destroyed as the result of land cultivation and overgrazing. Legumes adaptable for such lands include alfalfa and sweet clover primarily. Red clover is occasionally grown. Annual legumes include vetches and peas, usually spring seeded.

Seed-bed preparation is very desirable under these conditions; such preparation should aim at developing a fine, relatively firm seed-bed with the moisture as near the surface as is possible at seeding time. Seedings may be made either in the fall or spring, depending on the particular location. This point requires considerable attention as it is a very important factor in the establishment of satisfactory stands. The rate of seeding is dependent on the soil type and moisture supplies and constitution of the planting. The method most commonly used is power or horse-drawn machinery with a drill, the usual seeding machine.

Early management depends altogether on climatic and soil conditions with early utility depending on the growth.

Nurse crops are occasionally used, this depending again on soil moisture and fertility.

Short-time rotations including cereals and field peas are being more generally practiced, particularly in relatively intensively cultivated areas.

Irrigation is seldom a consideration in these areas as water supplies are very limited and the expenses of distribution high.

On summer fallow lands the range of grasses and legumes for use is not

as extensive as on the areas receiving 20 or more inches of rainfall per year. On these lands crested wheat, western wheat, native bunch grass, big blue grass and California brome (*Bromus polyanthus*) are most commonly used. Legumes include either alfalfa or sweet clover, depending on the range of soil moisture. At the lower soil moisture levels only the very hardiest of alfalfas are worth considering. Sweet clover has difficulty in making adequate growth.

Seed-bed preparation should be such as to develop a fine firm seed-bed, retaining all the moisture possible and keeping it relatively near the surface so that seed germination will be rapid and seedling growth thrifty. The method of seeding is by machinery to the largest extent possible. Either fall or spring seedings are made, dependent on climatic conditions.

The early management of new seedings has to be gauged altogether by climatic and soil moisture conditions.

It is in the lower rainfall areas of this section that the so-called typical range lands of the Pacific Northwest occur. Most of these lands at present are covered with a sparse growth of useful grasses and a relatively heavy growth of various kinds of shrubs, mostly sagebrush. The advisability of breaking up these lands is extremely questionable, and much argument exists as to the desirability as well as the advisability of seeding under any conditions. For the most part, these lands have been very seriously overgrazed and considerable soil has been lost. These range lands are largely in low rainfall belts where much of the moisture comes in the form of snow. The soil is very dry during most of the year. Cultivated grasses and legumes of value are relatively few, including primarily crested and western wheat and cereal rye. Seedings have been made under these conditions and fair stands secured where a fair seed-bed has been developed and the soil moisture conditions approximate to favorable. Plant growth has been very slow and considerable time elapses between time of seeding and time of utility. Seedings must be made at a low rate because soil moisture is not available to sustain heavy plant populations.

For the most part this range land has been benefited more by controlled grazing and proper grazing management than by artificial seeding. Wherever native plants, both grasses and legumes, are given an opportunity to develop and reseed, the productivity of the land has increased materially at considerably less expense and, in general, probably more rapidly than where soil cultivation and artificial seedings have been made or attempted.

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KEY TO COMMON PLANT NAMES

African Rhodes grass, *see* Rhodes grass
Alfalfa : *Medicago sativa*
Alfalfa hay : *Medicago sativa*
Alfalfa hay (U.S.A.) : *Medicago* spp.
Alfileria : *Erodium cicutarium*
Alsike (clover) : *Trifolium hybridum*
Alta fescue : *Festuca elatior arundinacea*
Annual white sweet clover : *Melilotus alba* var. *annua*
Astoria bent : *Agrostis tenuis* var. *astoriana*

Bahia grass : *Paspalum notatum*
Barley : *Hordeum vulgare*
Barley grass : *Hordeum murinum*
Barrel medic : *Medicago tribuloides*
Beans : *Vicia faba*
Bent : *Agrostis* spp.
Bermuda grass : *Cynodon dactylon*
Biennial sweet clover : *Melilotus alba* and *M. officinalis*
Big bluegrass : *Poa ampla*
Big trefoil : *Lotus uliginosus*
Birdsfoot trefoil : *Lotus corniculatus*
Blackberry : *Rubus fruticosus*
Black medic : *Medicago lupulina*
Blady grass : *Imperata cylindrica* var. *koenigii*
Blue couch grass : *Digitaria didactyla*
Blue grama : *Bouteloua gracilis*
Blue grasses : *Bothriochloa decipiens, B. intermedia* and *Dichanthium sericeum. See* also Kentucky bluegrass, Canada bluegrass, big bluegrass
Blue lupin : *Lupinus varius* = *L. angustifolius*
Boer lovegrass : *Eragrostis* spp.
Bracken : *Pteridium aquilinum*
Brigalow : *Acacia harpophylla*
Broad red clover, *see* Red clover
Brome grass : *Bromus inermis*
Broom corn millet : *Panicum miliaceum*
Broomsedge : *Andropogon virginicus*
Brown top : *Agrostis tenuis*
Buffalo grass : *Buchloë dactyloides*
Bulbous bluegrass : *Poa bulbosa*
Bur clover : *Medicago hispida*
Burnet : *Poterium sanguisorba*
Buttercup : *Ranunculus* spp.

California brome : *Bromus polyanthus*
California bur clover : *Medicago hispida*
Canada bluegrass : *Poa compressa*
Cape weed : *Cryptostemma calendulaceum*
Carpet grass : *Axonopus compressus*
Carpet grass (U.S.A.) : *A. affinis*
Catsear : *Hypochaeris radicata*
Cattail millet : *Pennisetum glaucum*
Caucasian bluestem : *Andropogon intermedius caucasicus*

Cheatgrass : *Bromus tectorum*
Chewing's fescue : *Festuca rubra* var. *fallax*
Chewing's fescue (U.S.A. Pacific Northwest region) : *Festuca rubra commutata*
Chicory : *Cichorium intybus*
Clover : *Trifolium* spp.
Clustered clover : *Trifolium glomeratum*
Coastal Bermuda grass, *see* Bermuda grass
Cocksfoot, *Dactylis glomerata*
Colonial bent, *Agrostis tenuis*
Common lespedeza : *Lespedeza striata*
Common millet, *see* Millet
Common white Dutch clover, *see* White clover
Common white sweet clover : *Melilotus alba*
Common yellow sweet clover : *Melilotus officinalis*
Corn (Great Britain) = Cereals
Corn (North America) : *Zea mays*
Cotton grass : *Trichachne* spp.
Cottonwood : *Cassinia leptophylla*
Cowpea : *Vigna sinensis*
Creeping fog : *Holcus mollis*
Creeping red fescue : *Festuca rubra stolonifera*
Crested dogstail : *Cynosurus cristatus*
Crested wheatgrass : *Agropyron cristatum*
Crimson clover : *Trifolium incarnatum*
Crowfoot : *Erodium botrys*
Crown millet, *see* Millet

Dallis grass : *Paspalum dilatatum*
Danish cocksfoot, *see* Cocksfoot
Danish white clover, *see* White clover
Danthonia tussock : *Danthonia raoulii* var. *rubra* and *D. flavescens*
Deer grass : *Muhlenbergia wrightii*
Dock : *Rumex* spp.
Dogstail, *see* Crested Dogstail
Domestic ryegrass, *see* Ryegrass
Drooping clover : *Trifolium cernuum*
Dryland browntop : *Agrostis tenuis* var.

Empire millet, *see* Millet
English Wild White clover, *see* White clover

Fescue : *Festuca* spp.
Festuca tussock : *Festuca novae-zealandiae*
Field peas : *Pisum sativum*
Fine-leaves fescues, *see* Fescue
Flatweed : *Hypochaeris radicata*
Flax : *Linum usitatissimum*
Fog, *see* Yorkshire fog
Foxtail millet : *Setaria italica*

Galleta grass : *Hilaria jamesii*
Giant White clover, *see* White clover
Gorse : *Ulex europaeus*
Green needlegrass : *Stipa viridula*
Guinea grass : *Panicum maximum*

Hairy vetch : *Vicia villosa*
Hard fern : *Paesia scaberula*
Harding grass : *Phalaris tuberosa* var.
Heather : *Calluna vulgaris*
Highland bent : *Agrostis tenuis oregonensis*
Hubam sweet clover : *Melilotus alba* var. *annualis*

Indian ricegrass : *Oryzopsis hymenoides*
Italian ryegrass : *Lolium multiflorum*

Japanese millet : *Panicum frumentaceum*
Johnson grass : *Sorghum halepense*

Kale : *Brassica oleracea*
Kanuka : *Leptospermum ericoides*
Kauri : *Agathis australis*
Kentish ryegrass, *see* Ryegrass
Kentish white clover, *see* White clover
Kentucky bluegrass : *Poa pratensis*
Kidney vetch : *Anthyllis vulneraria*
Kikuyu grass : *Pennisetum clandestinum*
Kobe lespedeza : *Lespedeza striata*
Korean lespedeza : *Lespedeza stipulacea*
Kudzu : *Pueraria thunbergiana*

Ladak alfalfa, *see* Alfalfa
Ladino clover : *Trifolium repens* var. *latum*
Lehmann lovegrass : *Eragrostis lehmanniana*
Louisiana white clover, *see* White clover
Low hop clover : *Trifolium procumbens*
Lucerne : *Medicago sativa*

Mammoth red clover : *Trifolium pratense perenne*
Mammoth white clover, *see* White clover
Manchuria milk vetch : *Astragalus cicer*
Mangolds : *Beta vulgaris* var.
Manuka : *Leptospermum scoparium*
Meadow fescue : *Festuca elatior*
Meadow foxtail : *Alopecurus pratensis*
Medium red clover, *see* Red clover
Millet : *Panicum miliaceum*
Millet (U.S.A.) : *Setaria italica*
Molasses grass : *Melinis minutiflora*
Montgomery red clover, *see* Red clover
Montgomery red clover (New Zealand) : *Trifolium pratense* var.
Mountain brome : *Bromus carinatus*
Mountain fescue, *see* Fescue
Mustard : *Brassica nigra*

Napier grass : *Pennisetum purpureum*
Natal grass : *Tricholaena rosea*
Native bunch grasses : *Agropyron*, *Poa*, *Festuca* and *Bromus*
New Zealand cocksfoot, *see* Cocksfoot
New Zealand white clover, *see* White clover
New Zealand Wild White clover, *see* White clover

Oats : *Avena sativa*
Onion-weed : *Romulea parviflora*
Orchard grass : *Dactylis glomerata*

Para grass : *Brachiaria mutica*
Para grass (U.S.A.) : *Panicum purpurascens*
Peas : *Pisum sativum*
Pennyroyal : *Mentha pulegium*
Perennial ryegrass : *Lolium perenne*
Persian clover : *Trifolium resupinatum*
Piripiri : *Acaena sanguisorba*
Poa tussock : *Poa caespitosa*, *P. colensoi* and *P. intermedia*
Poverty grass : *Danthonia spicata*
Prairie grass : *Bromus unioloides*
Prickly pear : *Opuntia* spp.
Proso millet : *Panicum miliaceum*

Rape : *Brassica napus*
Red clover : *Trifolium pratense*
Red fescue : *Festuca rubra*
Red top : *Agrostis alba*
Reed canary grass : *Phalaris arundinacea*
Rhodes grass : *Chloris gayana*
Ribgrass : *Plantago lanceolata*
Rice : *Oryza sativa*
Rothrock grama : *Bouteloua rothrockii*
Rough-stalked meadow grass : *Poa trivialis*
Rushes : *Juncus effusus*
Russian thistle, *see* Thistles
Russian wildrye : *Elymus sibiricus*
Rye : *Secale cereale*
Ryegrass : *Lolium* spp.

Sagebrush : *Artemisia tridentata*
Sainfoin : *Onobrychis sativa*
Salvation Jane : *Echium plantagineum*
Sand bluestem : *Andropogon hallii*
Sand dropseed : *Sporobolus cryptandrus*
Sand lovegrass : *Eragrostis trichodes*
Sand paspalum : *Paspalum stramineum*
Scabweed : *Raoulia australis*, *R. lutescens*
Scotch thistle, *see* Thistle
Seaside bent : *Agrostis palustris*
Sheep's fescue : *Festuca ovina*
Short-rotation ryegrass : *Lolium multiflorum* × *L. perenne*
Siberian millet, *see* Millet
Side-oats grama : *Bouteloua curtipendula*
Silver grass : *Festuca bromoides*
Slender wheatgrass : *Agropyron pauciflorum*
Smooth bromegrass : *Bromus inermis*
Sorghum : *Sorghum vulgare*

Sorrel : *Rumex* spp.
Soursob : *Oxalis cernua*
Soybeans : *Glycine soja*
Soybeans (U.S.A.) : *Soja max*
Stork's bill : *Erodium cicutarium*
Strawberry clover : *Trifolium fragiferum*
Striated clover : *Trifolium striatum*
Subterranean clover : *Trifolium subterraneum*
Suckling clover : *Trifolium dubium*
Sudan grass : *Sorghum sudanense*
Sudan grass (Australia and U.S.A.) : *Sorghum vulgare* var. *sudanense*
Swedes : *Brassica campestris* var.
Sweet clover : *Melilotus alba*
Sweet vernal : *Anthoxanthum odoratum*

Tall fescue : *Festuca arundinacea*
Tall meadow oatgrass : *Arrhenatherum elatius*
Tall oatgrass : *Arrhenatherum elatius*
Tanglehead : *Heteropogon contortus*
Tauhinu : *Pomaderris phylicaefolia*
Texas bluegrass : *Poa arachnifera*
Thistles : *Cirsium arvense*
Timothy : *Phleum pratense*
Tobosa : *Hilaria mutica*
Tor grass : *Brachypodium pinnatum*
Townsville lucerne : *Stylosanthes sundaica*
Trefoil : *Medicago lupulina*
Turkestan bluestem : *Andropogon ischaemum*
Turnips : *Brassica campestris*
Tussock grass : *Aira flexuosa*
Twitch : *Agrostis* spp.

Veldt grass : *Ehrharta calycina*
Velvet grass : *Notholcus lanatus*
Vetches : *Vicia* spp.
Vetches (U.S.A.) : *Vicia villosa* and *V. sativa*
Victorian Irrigation White Clover, *see* White clover

Water fern : *Histiopteris incisa*
Weeping lovegrass : *Eragrostis curvula*
Western ryegrass : *Agropyron pauciflorum*
Western wheatgrass : *Agropyron smithii*
Wheat : *Triticum vulgare*
White clover : *Trifolium repens*
White Dutch clover, *see* White clover
White millet, *see* Millet
White sweet clover, *see* Sweet clover
Wild Irishman : *Discaria toumatou*
Wild white clover, *see* White clover
Wimmera ryegrass : *Lolium rigidum*
Winter wheat, *see* Wheat
Winter wheat (U.S.A.) : *Triticum aestivum*

Yarrow : *Achillea millefolium*
Yorkshire fog : *Holcus lanatus*

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